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MICROCIRCULATION IN GRAFTED BONE

A Chamber Technique for Vital Microscopy of Rabbit Bone Transplants

T. ALBREKTSSON & B. ALBREKTSSON

Laboratory of Experimental Biology
Department of Anatomy, University of Gothenburg, Sweden

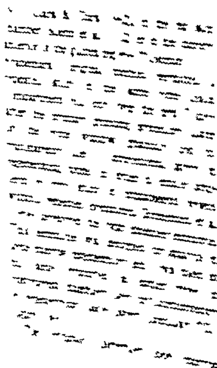
A method enabling in vivo observations of the microcirculation in orthotopically transplanted bone in the rabbit is presented. The technique permits repeated study of a well-defined bone tissue compartment both before and after grafting it as an autogenous or allogeneic transplant, respectively. It yields information about the reorganization of the microvascular system and the resorptive and formative processes in bone remodelling during incorporation of grafted bone. In the autologous experimental series, new capillaries were seen in the bone grafts 6 days after transplantation. No re-utilization of preexisting graft vessels was observed.

Key words: animal experiments; bone; ... microcirculation

Accepted 14

Biomicroscopy of the microcirculation in bone

Vital microscopy is the only technique that admits a *direct* and *simultaneous* registration of microvascular structure and function in a defined tissue compartment. Today refinements of the technique allow analysis of the intimate relationship between capillary structure, capillary topography and ... pattern at a resolving level of less than ... microns (Branemark 1966). A method for intravital microscopy of bone tissue ... was first described by Branemark ... By grinding down the rabbit ... transparency Branemark was able to ... microcirculation in the endosteal ... layers and in the bone marrow. Earlier ... observations of the microcirculation ... postnatal bone tissue ... heterotopical bone grafts ... ear chamber ... band ...



chamber consisted of a titanium framework enclosing a light-conducting quartz glass rod, separated by a small gap from a cover glass. Regenerating bone marrow filled the gap during the 3-week period following installation of the chamber in the metaphysis of the rabbit tibia Brånemark et al (1964) presented a report on their observations of marrow regeneration and microvascular behaviour during this time interval Using a modified Brånemark chamber, McCuscey et al (1971) and McClugage et al (1971, 1973) presented a detailed analysis of the microcirculation in regenerating bone marrow with special reference to the haemopoietic tissue elements.

Apart from the earlier studies of heterotropically grafted bone in the rabbit ear chamber mentioned above, there are also more recent ones (Ezra-Cohn et al 1969, Sudmann 1975)

Biomicroscopy of the microcirculation in orthotopically grafted bone

No intravital study of microvascular reactions in bone grafted to skeletal sites could be found in the literature The studies on the microvascular anatomy of orthotopically grafted bone published to date have been out with histological examination of fixed specimens (Stringa 1957, Ferguson et al 1959, Kingma & Hampke 1964, Albrektsson 1971)

Of course, neither the histological studies nor the heterotropical chamber graft observations mentioned above permit any conclusions about the revascularization dynamics in grafted bone during different stages of "graft take" at a skeletal host site

The aim of the present report is to describe a bone chamber technique enabling *in vivo* observations of orthotopically transplanted bone

MATERIAL AND METHODS

Modifications to the Brånemark chamber were needed to cope with the special problems

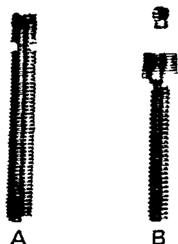


Figure 1 A Chamber type A for implantation the rabbit tibia Chamber length 28 mm out diameter 4 mm B Chamber type B f implantation in the rabbit tibia Chamber leng 25 mm, outer diameter of the lower part 4 mm. Th chamber type has a cover glass in a metal fra

associated with the transplantation procedu which demands limited dimension and maxim stability of the graft-chamber-graft bed compl Thus the bone transplantation chamber type (Figure 1A) consists of a hollow extern threaded titanium cylinder with an outer diame of 4 mm, containing two quartz glass ro (Vireosil*) separated by a 70–140 micron wi space The width of the space is defined interposing a suture thread (Ethilon monofil 7 0 microns, 6–0 100 microns 5–0 140 micron respectively) and the glass rods are glued position with Araldit* The type B chambe (Figure 1B) has, instead of the top glass rod, cover glass placed in a removable metal frame Th chamber type makes it possible to work with hig magnification (×23 ×55) water immers objectives.

The chambers were inserted in experiments, into the femur diaphysis, the diaphysis or the tibia metaphysis of male female Belgian hares or Half lop-eared rabbits least 8 months of age

* The chambers were skilfully manufactured by Kuikka Department of Anatomy University Goteborg

Installation of the chamber

The operations were carried out with the animals under general anaesthesia, maintained by i v injections of Nembutal Abbot at a dose of about 20 mg/kg body weight. Before the operation the animals were also given intraperitoneal injections of Valium, 1 mg/kg body weight.

Access to the chamber implantation site was gained by curved incisions through skin and fascia and by denudation of a circumscribed cortical bone area with the aid of a punch to cut the periosteum The periosteum was removed only from the precise bone area to be perforated by the drill. A 3 0 mm well sharpened spiral drill was used to make a hole through the proximal cortex, the marrow space and the distal cortex of the bone A 3 8 tap was used for [illegible] by saline irrigation was done to minimize the generated heat. Drilling was done with a speed of about 1,000 rev/min The chamber and all drills and screws are of titanium When the chamber was screwed into place, attention was paid to having the space in the proximal cortex oriented in the longitudinal direction of the bone, in the hope of achieving easier ingrowth of vascular tissue and bone into the observation area between the glass rods.

Registrations before grafting

Between 6 and 24 weeks after the implantation procedure the chamber was exposed via incisions in skin and fascia The leg of the rabbit was supported on a stand mounted on a cross stage enabling careful adjustment of the position of the leg without undue compression of the soft tissues. The chamber was immobilized in a special holder securing horizontal positioning of the chamber space Longitudinal movements of the leg with the chamber could be performed under controlled conditions by means of a micromanipulator The bone and vessel architecture of the "future graft" was registered on video tape and film before carrying out the grafting procedure (Figure 2).

The biomicroscopical registrations were performed using a Leitz intravital microscope modified for the purpose Objectives ×4–×55 together with eye-piece ×8 were used The microscope is provided with a magnification changer enabling zooming up to ×4 5 To this set up a TV-camera with video tape recorder, a Vinten scientific film camera and a Nikon ESR camera were connected.

A Leitz stereomicroscope with binocular tubes ×25 and objectives ×4 and ×10 was also used

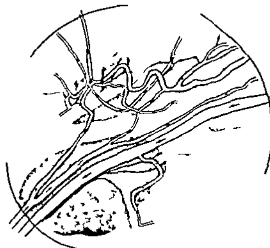


Figure 2 Low power view (drawing from photograph) of chamber space tissue The bone trabeculae (white) are seen between "islands" of connective tissue (dark) Vessels of varying width are crossing the microscope field Picture prior to transplantation, 7 weeks after chamber installation ×4

Transplantation of the incorporated chamber

All transplantations were performed a minimum of 6 weeks after the installation of the chamber at the donor site. The procedure was always initiated by preparing the host site A surgical procedure similar to that performed when the chamber was installed was now carried out on the contralateral extremity The hole in the bone was cut with a trephine drill with an outer diameter of 6 3 mm to make room for the excised cylinder containing the titanium chamber and an enveloping sheath of [illegible] to the prepared host site The technique described guaranteed an exact fit between graft and graft bed To ensure stability admitting vital microscopy at early intervals after grafting, the transplant was splinted to the host tibia using an osteosynthesis plate threaded on to the top of the chamber This plate was constructed in such a manner as to minimize the contact with the periosteum as can be seen in Figure 4

Registrations after grafting

At regular periods, beginning immediately after the grafting procedure, repeated intravital

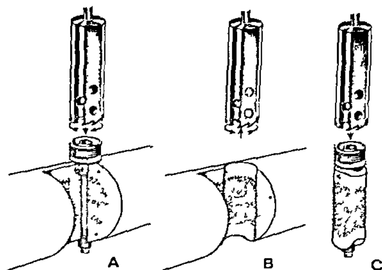


Figure 3 Schematic representati of the transplantation procedu A Under saline cooling a treph is used to cut out the chamber a surrounding bone and marr tissue B The trephine wi chamber and graft is lifted out the host bed (A bone window h been opened on drawings A and to get better visibility) Chamber and graft ready f implantation in a prefabricat hole in the contralateral extremity

observations were performed under light general anaesthesia, the only limiting factor being the risk of anaesthetical complications. Microvascular and remodelling dynamics in the bone layer interpositioned between the glass rods have been registered up to 1 year after grafting The sequences have been documented on film and video tape permitting graphical measurements a morphometrical analysis of bone remodelling different stages during the experimental period. was also possible to measure flow velocity At t end of the observation period contrast filling vessels allowed for *simultaneous* microang graphy and biomicroscopy After sacrificing t animals the tissues were prepared for histolo (Figure 5) and a comparison between intravital a histological findings was made.

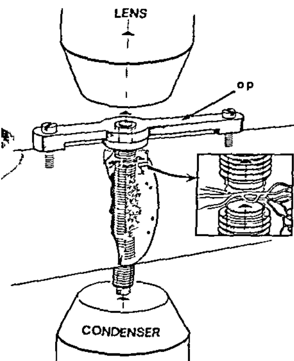
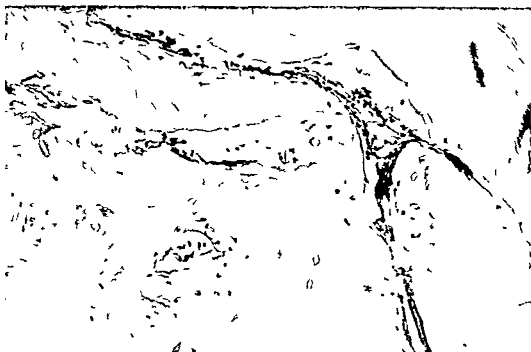


Figure 4 The chamber and graft in situ *Enlarged section shows the chamber gap with bone tissue and vessels This space is between 70 and 140 microns wide o p = osteosynthesis plate*

OBSERVATIONS AND DISCUSSION

Implantation sites

Different implantation sites were teste The rabbit *femur* diaphysis was found to b less suitable because of the risk of fracture When the chambers were transferred from a *ulnar* diaphysary donor to an ulnar host site the contralateral extremity incorporation of the implant occurred without fractures radius, via the ossified membrane, acted in the same way as biological splint (Albrektsson 1971) the transsected ulna However, the foreleg the rabbit was found to be less suitable purpose of vital microscopy because of problem of respiratory movements d the registrations. The proximal *tibia* found to be the most suitable site The med facet of the tibial metaphysis is close to th skin surface, it is flat and its cortex is d



ure 5 Histological section of the chamber space tissue 7 weeks after transplantation to a recipient site he rabbit tibia The section is taken from a part of the space where the bone post grafting by vital roscopy was proved to undergo resorption. The lacunae in the vicinity of the vessels contain osteocyte les indicating that the tissue is vital. Cement lines separating these vital osteocytes from the non-vital ts indicate that the vital bone probably has developed after grafting ×180

mogenous thickness facilitating a ndardization of the implantation and istration procedures.

e bone graft

The graft consists of a cortical bone collar th the incorporated chamber The part of graft that could be studied with the vital croscope is found in the chamber space is bone is a corticalized callus that has veloped after chamber insertion

vivo observations on bone tissue

In about 90 per cent of the cases the

ntrary to Brånemark et al (1964), who vestigated the marrow circulation, the chamber space in our experiments was placed within the cortex to ensure better conditions for the study of the different events in the hard tissue components. With the space within the cortex one avoided fat cells in the test tissue This gave better observation possibilities. The ingrowing tissue appeared in the form of bone ridges and a large amount of vessels of varying width (6–7 to 50 microns) Occasionally larger vessels (diameter 70–100 microns) were seen crossing the chamber gap, but these vessels did not give off any visible branches within the microscope field Changes in flow direction and vessel pattern from the early stages of "graft take" to animal sacrifice were registered. The corpuscular flow rate could be determined by the flying spot technique (Brånemark 1959)

Scattered "islands" of connective tissue in the bone made the identification of the bone ridges and their subsequent rebuilding easier

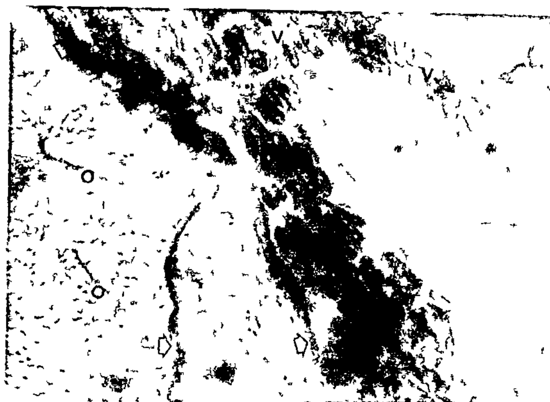


Figure 6 In vivo *microscopic view of the bone and vessels in the chamber space 6 months after insl*

to register Bone apposition and resorption was analysed morphometrically The resolution made it possible to identify osteocytes with canaliculae and to study individual red and white blood cells (Figure 6)

During the first week after transplantation it was possible to observe to and fro movements of blood corpuscles in pre-existing graft vessels. True circulation however was not observed in these vascular channels Four to five days after the transplantation procedure, circulation was observed in newly developed vessels in the chamber space These capillaries of 6–7 micron diameter were primarily confined to the connective tissue "islands" (see Figure 2) in the chamber space During the following weeks there appeared a network of regenerating vessels adjoining the bone trabeculae These vessels were of a calibre which amounted to between 6 and 40 microns From the second week postoperatively, a few vessels were observed to pierce the trabeculae After revascularization, parts c chamber bone tissue underwent resor whereas other, also revascularized, bone remained structurally unchanged for follo periods of several months

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CKNOWLEDGEMENT

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EFERENCES

lbrektsson, B (1971) Repair of diaphyseal defects. Thesis. 95 p University of Gothenburg

lgire, G H (1943) Microscopic studies of the early growth of a transplantable melanoma of the mouse, using the transparent chamber technique *J nat Cancer Inst* 4, 1–11

rånemark, P I (1958) A method for vital microscopy of mammalian bone marrow in situ. Lunds Universitets Årsskrift N F 2 Bd 54 Nr.2, 41 p

rånemark, P I (1959) Vital microscopy of bone marrow in rabbit. *Scand. J clin. Lab Invest* 2, Suppl 38, 11, 82 p

rånemark, P I, Breine, U, Johansson, B, Roylance P J, Rockert, H & Yoffey, J M (1964) Regeneration of bone marrow *Acta anat (Basel)* 59, 1–46

rånemark, P I (1966) [illegible]

[illegible]

ark, E R & Clark, E L (1942) Microscopic observations on new formation of cartilage and bone in the living mammal. *Amer J Anat* 70, 167–200

Ezra-Cohn, H E, Bullough, P G & Trueta, J (1969) The growth of bone autografts in rabbit ear chambers. *J Bone Jt Surg* 51-B, 372–379

Ferguson, A. B, Laing, P G, Grebner M & Madancy, L (1959) Study of revascularization of autogenous cortical bone grafts in rabbits using radiophosphorus *Arch Surg* 78, 551–555

Kiehn, C L, Cebul, F., Berg M., Gutentag, J & Glover, D M (1952) A study of the vascularization of experimental bone grafts by means of radioactive phosphorus and the transparent chamber *Ann Surg* 136, 404–411

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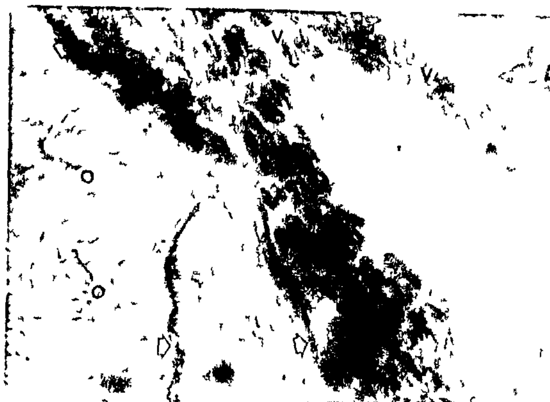
Sandison, J C. (1928) A method for the microscopic study of the growth of transplanted bone in the transparent chamber of the rabbit's ear *Anat Rec* 40, 41–49

Stringa, G (1957) Studies of the vascularization of bone grafts. *J Bone Jt Surg* 39-B, 395–420

Sudmann, E (1975) Vital microscopy of bone remodelling in rabbit ear chambers. *Acta orthop scand.*, Suppl 160, 115 p.

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I igure 6 In vivo microscopic view of the bone and vessels in the chamber space 6 mo iths after installa tion before transplantation The arrows indicate trabecular bone edges Arteriolar or venul ir vessels a often seen close to bone trabeculae V = Venule with erythrocytes O = Osteocyte lacuna with canal cul I hotograph in Leitz intravital microscope objective Leitz ×55 N A 0 65

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FERENCES

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rk, E R & Clark, E L. (1942) Microscopic observations on new formation of cartilage and bone in the living mammal *Amer J Anat* **70**, 167–200

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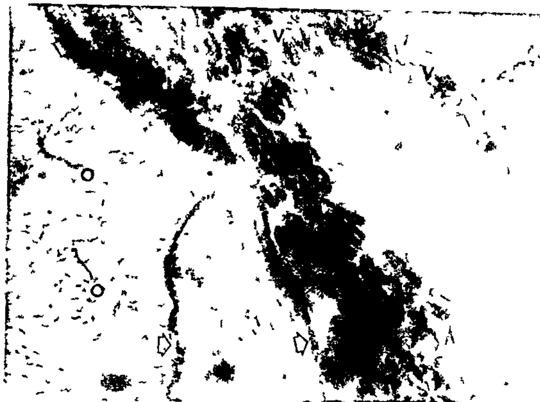


Figure 6 In
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Table 1 The patients and the total hip replacements studied

Age, sex, and body weight of patient	Disease for which total-hip replacement performed	Type of total-hip replacement	Duration of implantation	Reasons for removal	Skin sensitivity tests
61 years Female 50 kg	Osteoarthritis	McKee-Farrar	7 years	Severe bone loss	Negative to Co
72 years Female 59 kg	Osteoarthritis	Ring Thompson	3 years	Severe bone loss	Negative to Ni and Cr *slight response to Co*
62 years Female 71 kg	Osteoarthritis	Ring Thompson	3½ years	Slight bone loss	Negative to Ni and Cr
56 years Female wt. not known	Osteoarthritis	McKee-Farrar	6 years	Bone loss and proven sensitivity to Co and Cr	Positive to Co and Cr
52 years Female wt. not known	Osteoarthritis	McKee-Farar	10 months	Developed a sinus within three months – at no time was there any infection	Positive to Ni and Cr

elements above atomic number 11 In specimens where a closer examination of the metal/tissue interface is required, the implants are coated with a thin layer of carbon to prevent destruction of the tissues by the beam of electrons

Other metallurgical methods of analysis

In addition to scanning electron microscopy with EDXA and light microscopy other methods were used to examine the implants. Carbon arc emission spectroscopy was used for the semi-quantitative chemical analysis of the body tissues. The monomer content of PMMA bone cement was determined by monomer extraction and gas phase chromatography The PMMA-bone cement was examined by electron probe microanalysis which uses the wavelength dispersive analysis of X-rays after bombardment of the sample with electrons, in [illegible] microanalyser can detect elements with atomic numbers as low as 4 (carbon), compared with 11 (sodium) for EDXA.

Histological examination

Tissue removed at operation was examined using conventional staining and light microscopy

Bacteriological examination

The fluid, pultaceous material, and tissues about the implants were examined for sterility using plate and broth cultures.

Skin sensitivity tests

Solutions of 2 per cent cobalt chloride, 2 per cent potassium dichromate and 2 per cent nickel sulphate were applied to the skin for 48 hours. The results were read at 48 hours. An eczyematous reaction was read as a positive result, and an eczyamatous reaction with induration was read as a strongly positive result.

FINDINGS

Specimens from Patient 1

Clinical findings and naked eye observations

A McKee-Farrar total-hip replacement was removed, 7 years after its implantation, from a 68-year-old female patient Radiographic examination had revealed widespread loss of bone substance in the femur and pelvis about the left hip At the time of its surgical removal it was observed that, apart from the presence of a small amount of joint fluid, the femoral component was firmly held in the bone, whereas both the acetabular component and the screws were loosening On extraction of the acetabular component from the PMMA-bone cement, it was noticed that the cement/metal bond was extremely firm Similarly the one screw that was in the cement was tight The fibrous tissue layer, which was immediately against the polished areas and the distorted and polished spikes of the acetabular

pelvic surface was coloured green The tissue layer about the screw was also coloured green but only in three places in juxtaposition to the end of the screw the first few (polished) threads of the screw and the slot of the screw head A green crystalline film or deposit was present on the articular surfaces of both the acetabular cup and the femoral head on the pelvic side of the acetabular cup there were areas which showed polishing and some spikes were distorted The screws also showed areas of distortion and polishing on their tips and on the first few threads which were screwed directly into pelvic bone

Histological examination Sections from the tissue around the implant showed abundant lymphocytes in a poorly cellular fibrous matrix. Prominent foreign body giant cells surrounded spaces once occupied by material now dissolved out of the section which in this situation might be indicative of corrosion There was also much amorphous debris and fragments of either necrotic (dead) bone or plastic

SEM examination The sections of tissue and PMMA bone cement associated with the femoral stem of the Co–Cr–Mo C al implant were examined using the analyti and optical modes of the scanning electr microscope Spicules of bone could readily discerned and identified in the tissue Figur shows the tissue as revealed by the scann electron microscope in which pieces of h substance are evident The analytical mode the same field of view identifies calcium shown in Figure 2 Superpositioning of th two figures revealed the specific areas of bo No trace of cobalt was detected in the tis using these techniques.

Close examination of the inner surface the PMMA bone cement form from arou the femoral stem by scanning elect microscopy and EDXA revealed no evide of metallic elements from the implants on t surface of the PMMA bone cement Furt examination of the PMMA bone cement w the aid of the electron probe microanalyser both surfaces (that is adjacent to the femo stem at the metal/cement interface and at bone/cement interface) showed sm quantities of Cr and Mo on the side adjac to the metal/cement interface and no Cr significantly more Mo at the bone/cem interface No trace of Co was found in anot sample of PMMA-cement from the same a



Figure 1 Tissue removed from Patient 1 embedded and examined in the optical mode of the scanning electron microscope The arrows point to embedding medium (EM) and the bone tissue (BT)



Figure 2 Tissue removed from Patient 1 embedd and examined for Ca in the analytical mo (EDXA) of the scanning electron microscope T bright areas show Ca enrichment

The PMMA-cement removed from this patient was found to contain 3 per cent monomer, whereas 5 per cent monomer was found in a sample of PMMA-cement as prepared during a revision operation and examined for monomer at 7 days.

Figure 3 shows schematically the appearance of the articulating surface of the acetabular component There are four distinct areas, an inner surface showing wear, a green crystalline deposit, a thin ring of green proteinaceous material, and an outer zone of wear The green crystalline deposit observed by scanning electron microscopy is shown in Figure 4 which reveals the layering and its crystalline nature

Table 2 lists the analytical results obtained from the samples of this deposit on the EDXA attachment Molybdenum and cobalt were not detected. These figures are only to be interpreted semi-quantitatively However, the presence of Ca, Cr, P and S in approximately equal proportions suggests a mixed crystal of chromic sulphate and calcium phosphate (apatite) This is consistent with the view that chromium is not easily soluble in the body fluids, in contrast cobalt and molybdenum more readily dissolve and become dispersed throughout the body

A closer examination of one of the screws showed mild corrosion or etching, both of the tip (Figure 5) and of the first few threads which were screwed directly into the pelvis. A corrosion pit and areas of etching were found on the first thread and Ca was detected in the bottom of this corrosion pit This finding suggests that the type of attack present in the acetabular component and the screws is similar It should also be noted that the screws

Table 2 EDXA of the green crystalline deposit

Element	Count level (sample 1)	Count level (sample 2)
P	1217	1489
S	782	1172
Ca	1000	1143
Cr	972	943

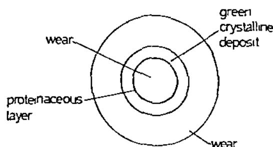


Figure 3 Schematic diagram of articular surface of the acetabular component removed from Patient 1 (not to scale) Note the four distinct areas as recorded in the text

were not manufactured by the commercial supplier of the prothesis so that the chemical reactions observed are likely to be specific to the Co–Cr–Mo–C alloy, rather than to the mode of manufacture.

A comparison of the type of attack observed at the screw tip (Figure 5) with the metallographic sections of the screw and the tip of the femoral stem showed that the distance between corrosion pits was of the order of microns whereas the grain, or crystalline, sizes of the screw and the stem were hundreds of microns and thousands of microns, respectively – that is the attack was general rather than intergranular The screw has a cored equiaxed grain structure whereas the femoral stem has a large grained dendritic cored structure, both structures are typical of Co–Cr–Mo–C alloys.

Discussion

The pathological and metallurgical findings from this patient together with the findings from Patients 2 and 3 suggest that dissolution of the Co–Cr–Mo–C alloy had occurred in life This corrosion would lead to the ions of Co, Cr, Ni and Mo being absorbed locally into the tissues. Because Co Ni and Mo ions appeared to be readily soluble in body fluids, they would be dispersed throughout the body In contrast at least some of the Cr ions were not dispersed and have clearly combined with calcium and phosphate ions (possibly from the bone) and sulphate ions (possibly from the

pelvic surface, was coloured green The tissue layer about the screw was also coloured green but only in three places in juxtaposition to the end of the screw, the first few (polished) threads of the screw, and the slot of the screw head A green crystalline film or deposit was present on the articular surfaces of both the acetabular cup and the femoral head, on the pelvic side of the acetabular cup there were areas which showed polishing and some spikes were distorted The screws also showed areas of distortion and polishing on their tips and on the first few threads which were screwed directly into pelvic bone

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blood) to produce the mixed crystal of chromic sulphate with some form of apatite

This interaction between chromium and calcium may have altered the balance of bone formation/resorption locally and contributed to the loss of bone substance from the femur and pelvis. It is possible that osteogenesis in this patient was particularly susceptible to the presence of such ions in her tissues. Moreover, bone necrosis may also have occurred due to the metallic ions released from the prosthesis, necrosis would also lead to local loss of bone substance

These hypotheses supplement the findings of other workers on metal sensitivity (Evans et al. 1974), and the increased cobalt and chromium contents in the hair, blood and urine of such patients (Coleman et al 1973)

The chromium sulphate/apatite crystals could explain the green colouration observed by orthopaedic surgeons both on Co–Cr–Mo–C alloy implants and in fibrous tissue adjacent to such implants.

Specimens from Patients 2 and 3

Clinical findings The next two specimens are similar in that they were both Ring-Thompson total-hip prostheses with cemented femoral stems in female patients In Patient 2, the prosthesis was removed after 3 years, when the patient showed widespread loss of bone substance in the femur and pelvis In Patient 3 there was a slight loss of bone substance in the pelvis three and a half years after implantation Initially the wear and corrosion characteristics are examined

Prosthesis wear Scanning electron microscopy of the articulating surface of the acetabular



Figure 6 Scanning electron micrograph of the articular surface of the acetabular component removed from Patient 2 Note the broad scratches resulting from corrosion.

eventual loss of bone both in the pelvis and femur as a by-product of the further dissolution of the wear products or the prostheses. The chemical reactions observed appear to be specific for the Co–Cr–Mo–C alloys used. Moreover these reactions possibly lead to the presence of resorbed bone adjacent to the prostheses.

The next part of the paper considers the responses observed to the presence of two McKee-Farrar total hip replacements in patients with proven sensitivity to Co, Cr or Ni.

Specimens from Patient 4

Clinical findings. A McKee-Farrar total-hip replacement was removed 6 years after its implantation from the right hip of a 62-year-old female patient. The patient had recently complained of pain and radio examination had revealed slight bone lo Tests had revealed that the patient sensitive to Co and Cr. At operation a large amount of bone loss in the wall.

SEM examination. Scanning elec microscopy of the articulating surface of acetabular component revealed the rod-like particles embedded in the tissue that surrounded the prosthe (Figure 8). The particles were 1–2 μm 0.2 μm in cross section. Table 5 shows results obtained with the EDXA There is enrichment of Cr within the These particles have been observed from ti to time in the last few years in our laborat both on bone plates and on prosthe removed from patients. They are usu



Figure 8. Scanning electron micrograph of collagenous tissue and rod-like particles. Note the size particle, 1–2 μm long × 0.2 μm in cross section.

Table 5 EDXA of the particle

	Energy	Integral
ayer	2.30 (S)	491
	5 42 (Cr)	1262
article	2.30 (S)	909
	5 42 (Cr)	2899

Co levels were present in each specimen.

able 6 Semi quantitative chemical analyses of tissue and fluid removed from Patient 4

Element	Tissue adjacent to acetabular component	Fluid in capsule
Ba	500–1700 ppm	<0 02 ppm
Ca	>1%	200 ppm
Co	<50 ppm	<1 ppm
Cr	170–500 ppm	<1 ppm
Fe	500–1700 ppm	20–60 ppm
K	>1%	>200 ppm
Mg	500–1700 ppm	20–60 ppm
Mo	<2 ppm	<0 2 ppm

ssociated with implant corrosion Other orkers (Vernon-Roberts 1976, personal communication), have observed similar particles nd they are only found on implants from atients of proven sensitivity to one of the onstituent elements of the Co–Cr–Mo–C loy used to fabricate the prostheses.

issue Table 6 lists the results of carbon arc mission spectroscopy of adjacent tissue and uid removed at the time of operation A ubstantial amount (up to 500 ppm) of Cr was ecorded in the soft tissue which lined the uter surface of the acetabular component

iscussion

The association of the particles with mplant corrosion and metal sensitivity uggests that they could be of immunological rigin Figure 9 outlines the possible formation nechanism, via chelation of the metal ion with rotein in the tissue to produce an antigen which would lead to an antibody response It s therefore likely that the particles are

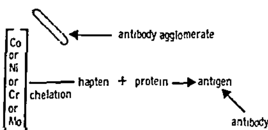


Figure 9 Antibody agglomerate formation mechanism

antibody agglomerates produced as a consequence of the patient's sensitivity to one of the constituent metals in the alloy, in this instance Cr

Specimens from Patient 5

Clinical findings This patient in her early fifties with severe bilateral osteoarthritis had a McKee-Farrar artificial hip joint inserted in her left hip Two weeks after the operation the wound was healed, the patient was free from pain on the operated side and was walking satisfactorily Within 3 months the patient developed a sinus, both the sinus discharge and the sinus tissue were sterile on culture. Subsequent dermatological tests showed that the patient was sensitive to Ni and Cr An inconclusive result was obtained from the test for Co The prosthesis was removed 10 months after operation after which the wound healed without any difficulty

Where there is minimal tissue response to the presence of Co–Cr–Mo–C alloys the colour of the soft collagenous tissue, which forms within a few days of insertion and remains throughout the implant's use, is white In this instance there was a grey deposit present in the articulating parts of the prosthesis, on the neck of the femoral component and the outer surface of the acetabular component

SEM examination The grey deposit immediately adjacent to the outer rims of the acetabular component was examined under the optical and analytical modes of the scanning

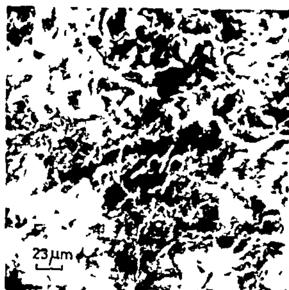


Figure 10 Grey deposit attached to the acetabular component removed from Patient 5 examined in the optical mode of the scanning electron microscope

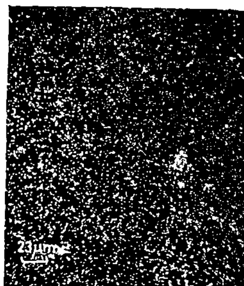


Figure 11 Grey deposit attached to the acetal component removed from Patient 5 examined f and Co in the analytical mode (EDXA) o scanning electron microscope The bright show Cr and Co enrichment

electron microscope Figure 9 shows the appearance of the deposit and Figure 10 shows the analytical mode of the same field of view identifying Cr and Co There are areas of Cr and Co enrichment

Discussion

The patient's metal sensitivity in this instance produced an unusual tissue response This tissue became enriched in Cr and Co and a sinus formed Nothing short of complete removal of the prosthesis was successful in getting the wound to heal

CONCLUSIONS

The findings from this study suggest

(1) Corrosion of Co–Cr–Mo–C alloy implants occurs in life The presence of this corrosion and the products of such corrosion can lead to loss of bone substance through either Co ion or Cr ion release

(2) The occurrence of metal sensitivity possibly induce an immunolog response or sinus formation

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REFERENCES

Coleman, R F, Herrington, J & Scales, J (1973) Concentration of wear products in h blood and urine after total hip replacem Brit med J 1, 527–529

Evans, E M, Freeman, M A R, Miller A J Vernon Roberts, B (1974) Metal sensitivity cause of bone necrosis and loosening of prosthesis in total joint replacement J Bone Surg 56-B, 626–642

Walker, P A & Gold, B L (1971) The tribol and friction lubrication and wear of me artificial hip joints Wear 17, 285–299

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STRESS FRACTURES CAUSED BY PHYSICAL EXERCISE

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A series of 142 stress fractures caused by sporting activities and physical exercise is presented. 121 fractures occurred in athletes and 21 in non-competitive sportsmen. Distance runners presented with 68 fractures, skiers 12, sprinters 10, orienteering runners 9, vaulters 3, and football players 3 fractures. Athletes engaged in other events had fewer stress fractures. 76 fractures occurred in the tibia, 26 in the metatarsal bones, 20 in the fibula, 5 in the femoral neck, 4 in the femoral shaft, and 2 in the metacarpal bones, lower pubic arch and sesamoid bones of the first MTP-joint. There was one fracture of each of the following: the humeral shaft, the ulna, the vertebral arch of L 5, the tarsal navicular and the proximal phalanx of the fifth toe. The treatment was generally a pause in training for 4–6 weeks, on the average. Running caused most of the stress fractures, the rest followed jumping exercises. The athletes mostly developed stress fractures during a period of alteration from one training session to another or during the preparation period close to the competition season. Joggers usually developed stress fractures 2–4 months after the beginning of regular training.

Key words: fracture, stress fracture, athletic injuries, physical exercise

Accepted 30 viii 77

Although the German army physician Breithaupt as early as 1855 described stress fracture in soldiers, stress fractures in athletes were not mentioned until several decades later (Pirker 1934, Baetzner 1936). With the growing interest in competitive sports and the development of sports medicine, more stress fractures have been found to occur in athletes (Burrows 1948, Devas & Sweetnam 1956, Devas 1969, Blazina et al. 1962, Arndt 1969, Brubacker & James 1974, Clement 1974, Apel & Metze 1975, Haluzicky & Szabad 1975, McBryde 1975). Stress fracture develops in a bone, without trauma, when it is rhythmically bending as a result of constant and long-lasting movement, muscular forces and mechanical stress. In both athletes and soldiers the same basic factors have been found to be the probable causes of stress fractures. These are, for example, the circumstances, methods and amount of training, skeletal framework, muscle fatigue and physical condition (Bernstein & Stone 1944, Weber 1967, Devas 1975). Gilbert & Johnson (1966) found fewer cases of stress fractures in army recruits who were in good physical condition and who had previously participated in sports. Although the physical condition as well as the strength of the skeleton of athletes is, in general, better than in soldiers (Nilsson & Westlin 1971), stress fractures occur nevertheless. Thorough studies of stress fractures in athletes are not available.

The aim of this study was to describe the stress fractures found in Finnish athletes and non-competitive sportsmen. Special attention

was paid to the connection between the intensity and amount of training and the appearance of stress fractures

PATIENTS AND METHODS

During the years 1968–1976, 142 stress fractures in athletes and non-competitive sportsmen were recorded

The median age of the patients was 22 years (range 10–51 years, Figure 1) Seventy-seven per cent of them were between 16 and 29 years There were 25 women (17 6 per cent) and 117 men (82 4 per cent)

Seventy fractures occurred on the right and 72 on the left side

The series consists of 68 middle- and long-distance runners, 12 skiers, 10 sprinters and hurdlers and 9 orienteering runners (Table 1) Non-competitive sportsmen sustained 21 fractures, they were all joggers

Most fractures occurred in April (20 per cent) Runners usually developed fractures in spring and autumn, joggers in autumn, and skiers during the snowless season Most women's fractures appeared in autumn

The number of patients with stress fractures amounted to about 1 per cent of the total number of athletes attending the clinic

Condition of training

In only 13 cases was the stress fracture a consequence of training other than running In 52

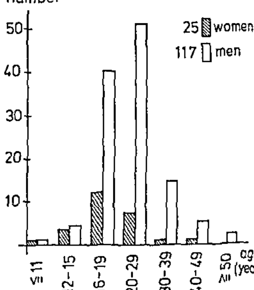


Figure 1 Age and sex distribution of patients w 142 stress fractures

long-distance runners (76 per cent) the amoun training preceding the appearance of the fracture was noted On the average they had running approximately 110 km/week F runners ran less than 100 km/week and eight than 150 km/week One athlete ran 200 km/w The skiers and orienteering runners did imately the same amount of training The trained over a distance of about 30–40 k Most of them had been practising regular

Table 1 Relation between sporting activity and stress fracture site

Sports \ Bone	Tibia	Metatarsal bones	Fibula	Femoral neck	Femoral shaft	Pubic arch	Metacarpal bones	Sesamoid bones	Humeral shaft	Ulna	Tarsal navicular	Toe phalanx	Vertebral arch	
Track and field	50	19	10	4	1				1					8
Jogging	7	5	5		1	2						1		2
Skiing	6	1	1	1	2			1						1
Orienteering	7		2											
Ball games	4	1	1							1	1			
Power events							2						1	
Gymnastics	2													
Cycling			1					1						
Total	76	26	20	5	4	2	2	2	1	1	1	1	1	14





Figure 2 Gamma camera scintigram of a stress fracture in the upper tibia of a distance runner The fracture was not visible in radiograms

exercise for only a few months before the onset of the symptoms of the stress fracture

Symptoms and diagnosis

The main symptom of the stress fracture was pain, which at an early stage appeared only after training, then during it, and later, even when walking The pain was at first diffuse in character, later localized. A characteristic symptom was pain caused by a pace- or stride shock. A palpable callus was often preceded by local swelling and tenderness.

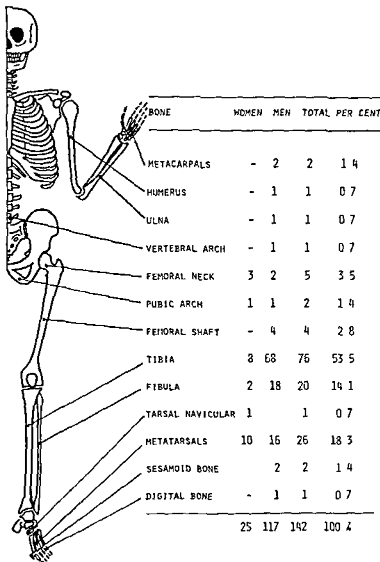
In most cases repeated radiograms were necessary to confirm the diagnosis. Initially a delicate fissure line might be seen, but usually the fracture became detectable only after callus formation. Tomography proved useful in the early stage Radioisotope-scanning (Sr^{85}, Tc^{99}) was positive before the radiological changes (Figure 2) which took 2–6 weeks to show up Isotope activity was increased for 1 year following healing of the fracture

Location

Ninety-five per cent of the stress fractures were found in the lower extremities and 5 per cent elsewhere in the skeleton (Figure 3). The relation between the site of fractures and the sports event is shown in Table 1

Seventy-six fractures occurred in the tibia (53 5 per cent). Most of them were located in the proximal and distal thirds of the shaft, whilst only two fractures appeared in the middle third. The fracture line was visible in about 40 per cent of the cases. Callus developed postero-medially in fractures of the upper and lower third (Figure 4), and anteriorly in the middle third fractures. The uppermost fractures did not become visible (as an increased internal density in the radiograms) until 2 months after the onset of symptoms. Usually the fracture extended through one cortex only and in a few cases through the whole bone

Ten out of 26 stress fractures in the metatarsal bones were in both the second and the third bone, four were in the fourth and two in the fifth bone Most of these fractures were located in the shaft



BONE	WOMEN	MEN	TOTAL	PER CENT
METACARPALS	-	2	2	1 4
HUMERUS	-	1	1	0 7
ULNA	-	1	1	0 7
VERTEBRAL ARCH	-	1	1	0 7
FEMORAL NECK	3	2	5	3 5
PUBIC ARCH	1	1	2	1 4
FEMORAL SHAFT	-	4	4	2 8
TIBIA	8	68	76	53 5
FIBULA	2	18	20	14 1
TARSAL NAVICULAR	1		1	0 7
METATARSALS	10	16	26	18 3
SESAMOID BONE		2	2	1 4
DIGITAL BONE	-	1	1	0 7
	25	117	142	100 4

Figure 3 Topographical locatio of stress fractures

and the neck A fusiform callus was characteristic of these fractures in radiograms

In the fibula 16 of the 20 stress fractures were located just proximal to the tibio-fibular syndesmosis All these fractures were caused by running Other fibular fractures followed jumping exercises.

Three distance-runners, one skier and one high-jumper presented with a stress fracture of the femoral neck Three of them were women The fractures were located infero-medially (Figure 6) X-ray changes developed 2–4 months after the onset of symptoms

In two athletes sesamoid stress fractures occurred in the medial bone of the first MTP-joint These fractures were easiest to observe in tangential projections Symptoms disapp without treatment in about 6 months.

Spondylolysis of the fifth lumbar vertebral appeared in a previously symptom-free jud Initial radiograms were normal. The diagnosis confirmed with oblique projections tomography 6 months later The scintigram (T was also positive During rest, sympt disappeared After 8 months the patient gradu returned to full training and soon afterwards the third prize in the Finnish Judo Championsh

Special features

Six partial stress fractures transformed complete fractures during training or competit



Figure 4 Stress fracture of the upper tibia in a distance runner A large callus is located posteriorly

Two of them were in the femoral shaft, two in the third metatarsal bone, one in the tibia, and one in the humerus.

Four female and eight male athletes presented with more than one fracture Seven of them had two consecutive stress fractures in different bones with an interval of approximately 11 months. Four men had two simultaneous fractures in different bones. Three consecutive stress fractures occurred in the tibias of one long-distance runner He was the only patient with a renewed stress fracture in the same bone

Treatment

Generally the treatment was limited to a pause in training lasting for 4–6 weeks. Normal activity was allowed A longer pause was needed in stress fractures of the upper tibia, femoral neck and shaft, pelvis, ulna and vertebral arch. In fractures of the femoral neck the pause lasted about half a year and in the fracture of the vertebral arch 8 months.

A plaster cast was used in five cases. Four of these were complete fractures. Eight patients needed crutches.

Two patients were treated by open surgery because of complete femoral shaft fractures.

Sick leave was required in 14 cases (9 8 per cent)

DISCUSSION

Stress fractures are caused by a certain disproportion between the load and the strength



Figure 5 Stress fracture of the lower tibia in a sprinter A Radiogram 3 weeks after the ons symptoms Oblique fracture just visible with thickening of both the anterior and posterior cortic

of the musculo-skeletal tissues. The bones do not have enough time to adapt to increasing and long-lasting mechanical stress. In the series presented above the amount of training of the endurance runners was 110 km/week, which is not particularly high, as modern endurance runners often run 250 km/week. The fitness joggers did 30–40 km/week which is also quite a moderate amount of training A common aetiological feature was a change in either the quality or the quantity of training This was most conspicious in joggers, who usually sustained stress fractures 2–3 months after the beginning of a regular training programme, just as soldiers get stress fractures in the months immediately follow recruiting (Gilbert & Johnson 1966, Wilsc Katz 1969) Similarly the seasonal variat are related to the changes in the trai programmes. Among the 12 patients ' sustained more than one fracture, indivi unknown factors may be of significa Running technique and psychological j disposition may be important

In the differential diagnosis both the defi bone diseases, tumours etc, and other over injuries of athletes must be considered (De 1975)

There were only nine children in the ser They all exercised significantly more th



3 *Radiogram after 6 weeks Oblique stress fracture clearly demonstrable*

children on the average This rare occurrence of stress fractures in children was also noted by Griffiths (1952) Berkebile (1964) and Zweymuller & Frank (1974)

The frequency and location of stress fractures differ in various materials of army recruits and athletes (Blazina et al 1962, Darby 1967, Devas 1975) In the present series more than half of all fractures were located in the tibia The same observation was made in previous Finnish series of soldiers stress fractures (Soderlund 1952, Salmela 1969) This high relative proportion of fractures in the tibia has never been reported elsewhere in the world On the other hand, fracture of the distal fibula is rare although it is considered common in athletes (Burrows 1948 Devas & Sweetnam 1956 McBryde 1975) No calcaneal stress fractures were found The general use of good sports shoes may explain this

Generally the only treatment needed is rest from sporting activities After 4–6 weeks break the athletes could gradually increase their training The risk of a stress fracture becoming complete is particularly great in fractures of the femoral shaft and neck (Provost & Morris 1969 Bargren et al 1971)



Figure 6 Three month-old stress fracture of the femoral neck in a female skier

REFERENCES

Apel, J & Metze, R. (1975) Ermudungsfrakturen bei Gewichthebern *Medizin & Sport* 15, 322–324

Arndt, K-H (1969) Ermudungsfrakturen jugendlicher Sportlern *Medizin & Sport* 9, 254–256

Baetzner, W (1936) *Sport- und Arbeitschaden* Thieme Verlag Leipzig [illegible]

[illegible] 1115–1117

Berkebile, R D (1964) Stress fracture of the tibia in children. *Amer J Roentgenol* 91, 588–596

Bernstein A. & Stone, J R (1944) March fracture A report of three hundred and seven cases and a new method of treatment *J Bone Jt Surg* 26, 743–750

Blazina, M E, Watanabe, R S & Drake, E C (1962) Fatigue fractures in track athletes *Calif Med* 97, 61–63

Brubacker, C E & James, S L (1974) Injuries to runners. *Amer J Sports Med* 2, 189–198

Burrows, H J (1948) Fatigue fractures of the fibula *J Bone Jt Surg* 30-B, 266–271

Clement, D B (1974) Tibial stress syndrome in athletes. *Amer J Sports Med* 2, 81–85

Darby, E (1967) Stress fracture of the os calcis *J Amer med Ass* 200, 1183–1184

Devas, M B & Sweetnam, R (1956) Stress fractures of the fibula *J Bone Jt Surg* 38-B 818–829

Devas, M B (1969) Stress fractures in athletes *Proc roy Soc Med* 62, 933–937

Devas, M B (1975) *Stress fractures* Churchill Livingstone, Edinburgh – London – New York

Gilbert, R S & Johnson H A (1966) Stress fracture in military recruits – A review of twelve years' experience *Milit Med* 8, 716–721

Griffiths, A. L (1952) Fatigue fracture of the fibula in childhood *Arch Dis Childh* 27, 552–557

Haluzicky, M & Szabad, F (1975) Fracture of long bones from fatigue in sportsmen *Acta Chir orthop Traum cech* 42, 72–75

McBryde, A. M (1975) Stress fractures in athletes *Amer J Sports Med* 3, 212–217

553–634

ovost, R A & Morris, J M (1969) *Fatigue fractures of the femoral shaft.* *J Bone Jt Surg* 51-A, 487–498

lmela, L (1969) Tutkimus varusmiesten marssimurtumista Porin Prikaatissa *Sotilaslääketiet Aik -L. 46, 12–16*

Söderlund, V (1952) Osteopathia itineraria *Sotilaslääketiet. Aik. L. 27*, 49–56

Weber, G (1967) Formen und Wandel der Überlastungsschäden des Knochens bei Soldaten. *Langenbecks Arch klin. Chir* 319, 409–412.

Wilson, E. S & Katz, F N (1969) Stress fractures. *Radiology* 92, 481–486

Zweymüller, K & Frank, W (1974) Ermudungsbrüche der Tibia im Kindesalter *Z Orthop 112, 450–460*

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FRACTURES OF THE OLECRANON

Analysis of 37 Consecutive Cases

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This study is based on 37 consecutive cases of fracture of the olecran treated during the period 1973–1975 The average follow up time wa years. The treatment was operative in all but two of the cases Superfic post-operative infection occurred in three cases and in three cases internal fixation failed due to porotic bone The transverse fractures hea more satisfactorily than the comminuted ones A short post-operative mobilization of 3 weeks or less gave the best results ($P<0.05$) In comparison of methods cerclage combined with two Kirschner wires g better results than cerclage alone

Key words elbow injuries, fracture fixation

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As a rule, fractures of the olecranon are treated operatively (Weber & Vasey 1963, Luther & Schulitz 1968, Bakalim & Wilppula 1971a, Colton 1973, Labitzke 1975), with the only exceptions being undislocated fractures and fractures in children (Scheuba & Unger 1970, Newell 1975) Many operative methods of treatment have been developed Wire loop fixation, intramedullary nailing (Kuntscher 1967), percutaneous Kirschner wires, the Zuelzer nail (Zuelzer 1958), plating, screw-fixation (Muller et al 1963), excision of the fragment with reinsertion of the triceps tendon (Bakalim & Wilppula 1971b) and tension wiring (Weber & Vasey 1963, Labitzke 1975)

The purpose of this paper was to find out which of the methods employed in this series gave the best results and what other factors influenced the results

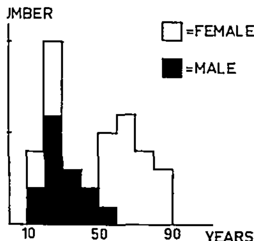
MATERIAL AND METHODS

The series is based on 37 consecutive fractures of the olecranon treated in the Surgical Hospital, *University Central Hospital, Helsinki, during* the period 1973–1975 The age and sex distribution of the patients is shown in Figure 1 Female patie were more numerous (23/14) All the male pat were under 60, whereas 13 of the female patie were over 60 years of age

The fracture was often sustained in a fall All fractures were dislocated except for one in a year-old boy Fifteen of the fractures w transverse, five oblique and 18 comminuted O patient had a fracture of both olecranons All th fractures were intra-articular and they we complicated in three cases One of the fractur was associated with luxation of the radial hea None of the patients showed any neurological o vascular deficit in the upper extremity

To evaluate the size of the proximal fragment the joint cavity was divided into degrees th distribution of the fractures is shown in Figure 2 In almost all of the cases the fracture fell within the sector 40–100° (34/37)

All but two of the patients were treated operatively The above-mentioned undislocated fracture in an adolescent was treated with a plaster of paris cast The other patient suffered from severe rheumatoid arthritis An olecranon fracture on the contralateral side had been treated operatively, but the osteosynthesis had failed du to severe osteoporosis



ure 1 Age and sex distribution of patients with olecranon fractures

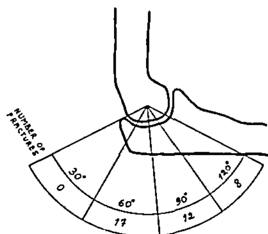


Figure 2 Distribution of the site of 37 olecranon fractures in the semilunar notch

Most of the fractures (24) were treated eratively within nine hours of the patient's ival at the casualty department In 19 cases the mary treatment was internal fixation with two rschner wires and cerclage (Table 2) A urniquet was used in almost all of the cases I/35) The operation time ranged from 30 min to iours (mean 1 hour)

The average duration of hospitalization was 5 ys (range 1–11 days) and that of plaster imbilization was 22 days (range 0–44 days). In 22 ses the internal fixation material was later noved under local anaesthesia.

The patients were requested to attend a follow- 2 years after the operation. For evaluation of the nical results the subjective and objective results re combined and scored as follows.

ccellent = symptom-free, motion equal to the act side

ood = occasional pain or restriction of motion less 10°

ur = occasional pain and restriction of motion less 30°, or over 30° with no pain

oor = occasional pain with restriction of motion er 30°

he statistical significance was studied with the i-square and *t* tests.

ESULTS

t follow-up 20 out of 35 operatively-treated itients were entirely symptom-free, 10 had occasional pain or pain after strenuous exercise, and two were not evaluated because of rheumatoid arthritis. Loss of rotation was found in two patients, 15° in one and 90° in the other Loss of extension-flexion was seen in 20 patients 1–10° in seven, 11–30° in six and over 30° in seven patients. In 28 cases the radiological result was good, whereas in the remaining seven there were clear post-traumatic arthrotic changes.

Patients under 50 did better than the older ones and the results of the men were better than those of the women, although these findings were not significant Transverse fractures healed, as was expected, better than the comminuted fractures (Table 1) When the immobilization time was 3 weeks or less the result was significantly better than when plaster was used for more than 3 weeks (Table 3), regardless of the degree of comminution

Three patients developed a superficial infection and failure of the osteosynthesis was observed in another three In the first case of failure of the internal fixation, the primary result was good, but the wire loop behind the Kirschner wire loosened. The patient was treated with cortisone for rheumatoid arthritis and she had a superficial infection post-

Table 1 Effect of fracture type on results

Fracture type	Results				
	Excellent	Good	Fair	Poor	Total
Comminuted	6	3	7	2	18
Transverse	5	4	4	0	13
Oblique	2	0	2	0	4
Total	13	7	13	2	35

Table 2 Effect of methods on results

Method	Results				
	Excellent	Good	Fair	Poor	Total
2 Kirschner wires and cerclage	6	6	6	1	20*
Screw	4		3	1	8
Simple wire loop	1	1	4		6
Resection	1				1
Total	13	7	13	2	35

* The results of one patient were not evaluated because of severe rheumatoid arthritis

Table 3 Effect of immobilization on results

Immobilization (days)	Results				
	Excellent	Good	Fair	Poor	Total
0–21	9	6	4	1	20*
22–44	4	1	9	1	15
Total	13	7	13	2	35

* $P < 0.05$

operatively The second failure was an elderly woman with osteoporosis, the screw used for the osteosynthesis pierced the proximal fragment In a second operation a new osteosynthesis was performed with two Kirschner wires and a wire loop, resulting in arthrosis In the third failure, the osteosynthesis was performed with a simple wire loop which cut through the proximal fragment

Patients without associated injuries were off work between 21 and 236 days (mean 77 days)

DISCUSSION

The age distribution is similar to that repor in previous papers (Luther & Schulitz 19 Scheuba & Unger 1970) In this material, the patients over 60 were women When t fracture line passed through the corono process or distal to it, it was not considered fracture of the olecranon (Rauber & Kop 1955) This is in contrast to the classifica used by some other authors, for examp Luther & Schulitz and Scheuba & Unger

The clinical results were similar to those sented by Bakalim & Wilppula (1971a, b), ever, the number of poor results was ller in the present series. The results were ter for the male than for the female ients, the explanation is probably the ater incidence of osteoporosis and the more anced age of the female patients. The riction of mobility in the present series was ller than in the materials presented by her & Schultz (1968) and Scheuba & ger (1970) They put greater emphasis on servative treatment The eight patients re-mined in the series of Weber & Vasey 63) all had a restriction of under 10°. alim & Wilppula suggest that their itively high incidence of limitation of vement might be attributed to the relatively g average duration of immobilization (6 eks in operatively treated cases) mobilization for over 6 weeks seemed to ve an unfavourable effect on the results. At sent, there is a trend towards short im-bilization, for example, Weber & Vasey ommend a plaster cast for only 4 days. In present series the average duration of im-bilization was 22 days.

In one case the head of the screw cut rough the proximal fragment A washer ght have prevented this occurring in the rotic bone Stable internal fixation can be hieved with a screw in transverse and lique fractures of the olecranon It may not ways succeed in comminuted fractures, too in or too short a screw will lead to a failure, d too thick a screw may split the fragment dislocate the fracture

In conclusion, we suggest that internal xation with two Kirschner wires and cerclage cording to Weber & Vasey (1963) should be the method of choice in treating fractures of the olecranon in most cases. A period of im-mobilization of 3 weeks or less is recommended.

REFERENCES

Bakalim, G & Wilppula, E (1971a) Fractures of the olecranon I *Ann Chir Gynaec Fenn.* **60**, 95–101

Bakalim, G & Wilppula, E (1971b) Fractures of the olecranon II *Ann. Chir Gynaec Fenn.* **60**, 102–104

Colton, C. L. (1973) Fractures of the olecranon in adults classification and management. *Injury* **5**, 121–129

Küntscher, G (1967) *Practice of intramedullary nailing* pp 239–240 Charles C Thomas, Springfield.

Labitzke, R. (1975) Überlegungen zur Theorie der Zuggurtung Ermittlung der optimalen Metall-anordnung bei dorsaler Zuggurtung einer Olecranonfraktur *Arch orthop Unfall-Chir* **81**, 179–192.

Luther, R & Schultz, K (1968) Zur Behandlung der Olecranonfrakturen. *Mschr Unfallheilk.* **71**, 213–220

[illegible] Allgower, M & Willenegger, H (1965) [illegible] *Injury* **7**, 33–36

Rauber & Kopsch (1975) *Lehrbuch und Atlas der Anatomie des Menschen.* Vol. 1, 19th ed., pp 207–209 G Thieme Verlag Stuttgart

Scheuba, G & Unger, F (1970) Einteilung und Behandlung der Olecranonfrakturen *Mschr Unfallheilk* **73**, 220–227

Weber, B & Vasey, H (1963) Osteosynthese bei Olecranonfraktur *Z Unfallmed Berufskr* **2**, 90–96

Zuelzer W (1958) *Chirurgische Operationslehre* Vol 6, p 255 Johann Ambrosius Barth, Leipzig Cited by Bier-Braun-Kummel

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FRACTURE OF THE RADIAL NECK IN CHILDREN

A Long-Term Follow-up Study of 43 Cases

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A series of 43 radial neck or head fractures in children was analysed respect to the type of fracture and whether conservative or surgical trea had been employed Thirty-seven patients were examined after a foll period of 1–18 years (average 8 years) Tilting of the radial head the l *of the radius and the size of the radial head were measured roentgenolo* to evaluate any growth disturbances The results were good in 24, fair and poor in 3 cases. In the 14 patients treated surgically results were g five, fair in six and poor in three cases All but two of these patients h angulation of the radial head of 30° or more The result was good in 20 23 patients who were treated conservatively because the angulation w than 30° after reduction In fair and poor cases the function was impai the limitation of motion Disturbances in growth were generally slight, l enlargement of the radial head was observed in 16 cases at the follo

Key words fracture, radial neck, children, long term follow-up

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Fractures of the radial neck or head are relatively uncommon in children The frequency varies between 4 5 and 10 per cent of all fractures in the elbow region (Blount 1955, O'Brien 1965, Henrikson 1969, Tachdjian 1972) A fall on the outstretched arm compresses the capitellum against the outer side of the head of the radius, tilting and displacing it outwards and forwards The valgus strain can cause an avulsion of the ulnar epicondyle (Dunlop 1935), a rupture of the ulnar collateral ligament or capsule or even a fracture of the olecranon or the upper shaft of the ulna (Jeffery 1950) In about half of the cases of radial neck fracture the proximal radial epiphysis is also involved (Jones & Esah 1971) When the fracture line is lower, a greenstick fracture of the neck of the radius may occur (Jeffery 1950, Watson-Jones 1955) According to the authors mentioned above fracture of the radial head rarely occu children

The following complications have described in the literature

1) New bone formation and deformity o radial head with enlargement (Blount l Fielding 1964, O'Brien 1965, Jones & l 1971)

2) Avascular necrosis of the radial h and/or premature fusion of the epiphy plate resulting in a shortening of the radius cubitus valgus deformity may be the re (Jeffery 1950, O'Brien 1965, Henrikson 19 Jones & Esah 1971) On the other hand Re & van Gorder (1963) did not find shortening of the radius in spite of premat fusion of the upper radial epiphysis.

3) Fibrous adhesions or crossed synost between the radius and ulna limiting rotation mobility (Fielding 1965).

A combination of two or more of these nplications, resulting in most cases in a ppling deformity

In our series we have analysed the long-m results of radial neck or head fractures in ildren treated conservatively or surgically ecial attention was given to any growth mplications and the causes of possible strictions of motion The prognostic diological criteria in the evaluation of the d results and the indications for surgical :atment are discussed.

ATIENTS AND METHODS

tients

he present series consists of all fractures of the

[illegible]

157–1975 Of the total number of 43 patients, 37 ere examined by the authors in 1976 The maining six patients were followed up as itpatients until the fracture had healed and the otion of the elbow was satisfactory, but because a ersonal after-examination was lacking, these six itients were excluded from the follow-up study he ratio of boys to girls was 18 25 The age of e patients at the moment of injury varied from 5 14 years with an average of 10 years. The ghest frequency of fractures was found in the

[illegible]

eight.

ype of fracture

There were no open fractures. There were 21 ases of fracture-separation of the proximal piphysis and 21 cases of greenstick fracture of the eck with angulation The remaining case was a mall marginal fracture of the radial head.

The tilting of the radial head or fragment was adial in 42 cases and medial in only one case In 25 ases the radial head was tilted anteriorly and in en cases (23 per cent) posteriorly In seven cases he radial head was completely displaced with total eparation of the epiphysis.

Associated injuries

Associated injuries of the elbow were found in 34 per cent (16/43) Five patients had an avulsion fracture of the ulnar epicondyle Four patients had fractures of the olecranon, one patient a fracture of the upper part of the shaft of the ulna. Posterior luxation of the arm occurred in two cases. Avulsion fractures of the coronoid process, intra-articular avulsion fracture of the lateral proximal part of the ulna (insertion of the ligamentum annulare) and fracture of the capitellum of the humerus were found in one case each. There was partial radial paresis in one case but it regressed completely within 8 weeks. The nerve was not explored There were no vascular complications in this series.

Treatment

Closed reduction was done in 19 cases, ten cases with angulation less than 25° were immobilized without reduction. Of the total number of patients 32 per cent (14/43) were treated surgically Open reduction was indicated when the angulation of the radial head could not be corrected up to 25° in both planes by closed means. An operation was also performed in cases of a complete epiphyseal separation or a dislocated marginal fragment of the radial head There were only two exceptions to these indications. One case with radial tilting of only 20° was operated on, because of radial and anterior displacement of about one half of the bone diameter One case treated elsewhere was first seen in our hospital 4 weeks after the injury The remaining case with radial tilting of 65° was left and no operation was performed.

Fixation of the radial head was done with catgut in 10 cases and a Kirschner wire through the radiohumeral joint in three cases. A small marginal fragment was removed in one case One reoperation was performed in a case of failure of the reduction position after the first operation, in which the totally anteriorly displaced radial head was fixed with catgut sutures through the soft tissues.

Plaster immobilization was used in 42 cases and a cuff and sling in only one case. The average time in plaster was 33 days, range 15 to 63 days. There were no passive physical exercises.

Methods of investigation

Tilting of the radial head was measured on both the antero-posterior and lateral projections of both arms on the date of injury, at the end of treatment and at the follow-up Measurements were made to an accuracy of 5° The differences in these angles compared with the values of the healthy arm were

registered The size of the radial head was also measured at the follow-up Differences of more than 2 mm between the fractured and non fractured sides were recorded The primary radiographs of all 43 patients and those of the 37 patients followed up were compared

At the clinical after-examination the carrying angle and the lengths of the radius and the ulna were measured If there was any suspicion of a difference in the lengths of the two arms, the lengths of the radius and ulna were measured roentgenologically The range of motion of the elbow was measured on both arms.

Follow-up examination

The follow-up period ranged from 1 to 18 years with an average of 8 years. The age of the patients at follow-up varied between 8 and 19 years, average 17 years.

The end result was to be judged good, if restriction of any of the movements of the elbow joint was less than 10° compared with that on the healthy side, or the difference in the carrying angle (CA) was less than 10° Values from 10 to 30° were graded fair, and the end result was classified as poor if restriction of any of the movements was more than 30°

RESULTS

In this series the radial angulation of the normal contralateral radial head varied between 0 and 15°, average 12 5° The angulation of the normal radial head forwards or backwards varied from 10° forwards to 5° backwards, being 3 5° forwards on average

The end results according to the criteria mentioned above (Table 1) were good in 65 per cent (24/37), fair in 27 per cent (10/37), and poor in 8 per cent (3/37) The type of treatment in the various classifications t primary angulation is also seen in Table 1 S of the ten fair cases and all the three poor cas were treated surgically Out of eigh operatively treated cases with total primar displacement the end result was good or fair i five cases

Correction of angulation

The spontaneous correction of the angulation of the radial head was generall 10° or less during the period of growth, wit an average 9 3°

Complications

There were three poor results in this seri two cases of synostosis between the radius a ulna with complete limitation of rotation a one case of aseptic necrosis of the radial hea In the latter case the arm was dislocat posteriorly and the radial head tota displaced anteriorly Because of redislocati of the radial head, reoperation was perform but an aseptic necrosis occurred The rad head was excised, but fibrous adhesio limited rotation to 60° The same type injury with posterior dislocation was pres in another operatively treated case resulting radio-ulnar synostosis (Figure 1) Resection the synostosis and the radial head resulted 80° of rotational movement In the seco case of synostosis operative reduction faile with an anterior and radial displacement of the radial head of about half of the diameter of the radial neck A large mass of callus

Table 1 End results at the follow-up

Primary angulation (degrees)	Good Non-op	Good Op	Fair Non-op	Fair Op	Poor Non-op	Poor Op	Total
<30	14	1	3	0	0	1	19
30–60	5	1	0	4	0	0	10
>60	0	3	1	2	0	2	8
Total	19	5	4	6	0	3	37
	24 (65 %)		10 (27 %)		3 (8 %)		



gure 1A A 14-year old boy Fracture of the left radial neck with epiphyseolysis and total anterior splacement Lateral projection There was also posterior dislocation of the elbow which was reduced in e emergency room

A good position of the fracture after surgical reduction

C On the twenty-third day when the plaster was removed signs of myositis ossificans can be seen.

ositis ossificans developed A resection ration similar to that performed in the er case of synostosis is planned for the end he growth period in this case

n 43 per cent (16/37) enlargement of the ial head was observed. The increase was m 3 to 14 mm The limitation of rotation ounted to more than 30° in three of these ients, while a limitation of 15–30° was served in seven patients. In three patients it s less than 15° and in three patients there s no limitation of motion. In ten cases open uction was performed The distribution of primary displacement of these 16 cases s almost the same as in the three placement groups.

Myositis ossificans (M.O) was found in 32 cent (14/43) In most cases the signs of O on the radiograph were situated in front the proximal part of the ulna corresponding the ulnar insertion of the supinator muscle ven patients were treated surgically In ee of these and in four cases treated con- vatively the signs of M O had disappeared the follow-up and the end result was good the remaining seven cases slight changes dicative of M O were observed on the diographs at the follow-up, with limitation motion lowering the end result grading to r or poor However the combination of nostosis, or necrosis of the radial head, and O was the main cause of poor results in is series.

In two cases the radial head was excised and four other cases the radius was 3–9 mm orter than on the healthy side The cubital rrying angle varied between 5 and 25°, the ifference being 10° or less than on the ealthy side The average carrying angle was 2.5° on the healthy side, and 14 8° on the jured side

ISCUSSION

he reported incidence of other injuries in the lbow region associated with fracture of the adial neck is between 12 and 30 per cent Jeffery 1950, Reidy & van Gorder 1963,) Brien 1965, Jones & Esah 1971) In our series it was 34 per cent Posterior luxation of the arm was found primarily in two of the cases later classified as poor and seemed to indicate a poor prognosis in fracture of the radial neck

An enlargement and deformity of the radial head were found in 43 per cent (16/37) of our cases. This phenomenon was reported by O'Brien (1965) in 12 per cent (15/125) and by Jones & Esah (1971) in 13 per cent (4/30) The higher incidence in our series may be due to the strict criteria used for measuring the radial head in both projections. The deformity of the radial head generally caused slight limitation of rotation

The serious complication, avascular necrosis of the radial head, seems to occur quite infrequently and generally in less than 10 per cent of cases. Jeffery (1950) reported one case of excision of the radial head (1/24). Reidy & van Gorder (1963) reported one aseptic necrosis of the radial head (1/30) and Jones & Esah (1971) three cases (3/34) This complication occurred in one case (1/37) in our series.

A premature fusion of the epiphyseal plate may be expected in epiphyseal injuries of the radial neck (Jeffery 1950) O'Brien (1965) reported this complication in as many as 40 out of a total of 125 cases. However this complication seldom resulted in marked shortening of the radius and/or cubitus valgus, and was of no clinical significance (Reidy & van Gorder 1963, O'Brien 1965, Henrikson 1969, Jones & Esah 1971) O'Brien (1965) found shortening of the radius in only five cases (5/125) We also agree that this complication poses no serious problems. This may be due to the fact that the radius grows mainly from the distal epiphysis.

Fibrous adhesions or crossed synostosis between the radius and ulna limit the rotation mobility (Fielding 1964) O'Brien (1965) found synostosis in six cases (6/125), Henrikson (1969) in three cases (3/55) and Jones & Esah (1971) in one case (1/30) This severe complication was present in two cases (2/37) in our series. Resection of the synostosis and the radial head was performed later, at the end

of the growth period, in one case, resulting in satisfactory rotation

Myositis ossificans changes did not cause serious problems In half of the cases with M O the calcifications disappeared, if they remained the motion was slightly limited

Henrikson (1969) and Jones & Esah (1971) reported poor results in 15 and 23 per cent of their cases Using similar criteria we found poor end results in 19 per cent

In order to prevent the complications mentioned above, Stankovic et al (1975) suggested operative treatment when tilting amounted to 20° or more Other authors prefer conservative reduction in cases of tilting between 30 and 60°, and reserve open surgery for cases with tilting of more than 60° (Jeffery 1950, Blount 1955, O'Brien 1965, Jones & Esah 1971, Sharrard 1971, Tachdjian 1972)

In conclusion we suggest the following treatment guidelines

1 In cases with angular displacement of less than 30° the need for reduction is questionable A plaster or sling immobilization for 2–3 weeks is sufficient

2 Cases with angular displacement between 30 and 60° should be treated by closed reduction If this is not successful, surgical reduction is indicated

3 Cases with displacement of more than 60° usually require surgical intervention

REFERENCES

Blount W P (1955) *Fractures in childr* 56–57 Williams & Wilkins Co Baltimor

following displacement of the proxima epiphysis *J Bone Jt Surg* 46-A 1277

Henrikson, B (1969) *Isolated fractures* proximal end of the radius in c Epidemiology, treatment and prognosi *orthop scand* 40, 246–260

Jeffery, C C (1950) Fractures of the head radius in children. *J Bone Jt Surg* *314–324*

Jones, E R L & Esah M (1971) Di fractures of the neck of the radius in chil *Bone Jt Surg* 53 B, 429–439

O Brien P J (1965) Injuries involvi proximal radial epiphysis *Clin Orth* *51–58*

Reidy, J A & van Gorder, G W (1963) of displacement of the proximal radial ep *J Bone Jt Surg* 45-A 1355–1372

Sharrard, W J W (1971) *Paediatric ortho and fractures* pp 972–975 Blackwell *Publishers Oxford and Edinburgh.*

Stankovic, P, Emmermann, H Burkhard Krtsch, U (1975) Die Frakturen des pro Radius im Kindesalter *Z Kinderch* 77–86

Edinburgh.

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:DUCTION OF DISPLACED SUPRACONDYLAR .ACTURE OF THE HUMERUS IN IILDREN BY MANIPULATION IN FLEXION

JLFOTOOH M EID

Sixty-one children with posteriorly displaced supracondylar fractures of the humerus were treated by manipulation with the elbow flexed 40°–60° This

being used Redisplacement occurred in only 8 2 per cent of the patients and in none of these was it severe enough to justify remanipulation

Key words supracondylar fracture, humerus

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ny different methods have been described the treatment of displaced supracondylar :tures of the humerus in children Similarly, :hods of fixation vary widely This paper orts a method for reduction and fixation ich has proved easy to utilize, and is more able and safer than the other methods cribed

ITERIAL

ty-one children with posteriorly displaced racondylar fracture of the humerus (Grade III :tures in which there is no contact between the ;ments) were treated by the author and followed during the period from 1970 to 1976 There e 43 boys and 15 girls. Their ages ranged from to 15 years. Treatment was carried out 3 to 48 irs from the time of injury In seven patients, vious attempts at reduction had been made and our of these reduction was tried more than once six patients the elbow region was grossly ollen.

Associated injuries included

i) *Skin and soft tissues* Bruising on the medial side of the elbow was present in 42 patients (68 9 per cent) In 18 of these (42.9 per cent) the skin was perforated by the sharp lower end of the proximal fragment

ii) *Vascular injuries* One patient presented with a cyanotic hand and forearm (1 6 per cent) In 15 patients (24 6 per cent) the radial pulse was not palpable but there was normal capillary circulation in the nail beds

iii) *Nerve injuries* Six patients (9 8 per cent) had nerve injuries. Two of them showed median nerve compression and in four the radial nerve was involved.

METHODS

Method of reduction

Reduction was carried out under general anaesthesia as soon as the child was considered to be fit Traction was applied to the forearm, with the elbow flexed 40°–60° against counter traction from the axilla (Figure 1) This was continued until the upward displacement was corrected. Lateral displacement was then corrected by lateral pressure between the thumb and fingers of one of the operator's hands, the other hand maintaining traction (Figure 2). With traction still maintained the posterior displacement was corrected next. The



Figure 1 First step manipulation reduction of upward displacement

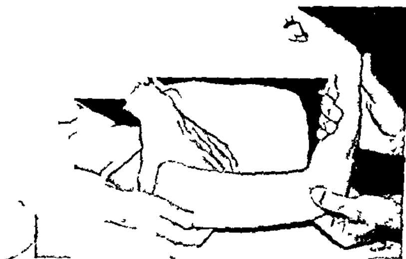


Figure 2 Second step in manip tion reduction of lateral disp ment

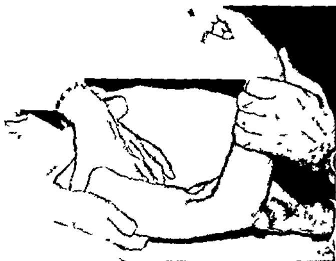


Figure 3 Third step in manipu tion reduction of posterior dis placement

ımb of the surgeon's manipulating hand was ıced behind the olecranon, pushing it and the ıtal fragment anteriorly, while the fingers of the ne hand pushed the front of the proximal gment posteriorly (Figure 3) At this stage, :ational displacement should have been corrected the tenseness of the tissues around the fracture harnley 1968) If this had not occurred, the distal ıgment was rotated externally until the ıcondyles were re-aligned with the epicondylar lges of the proximal fragment (McLaughlin & ımson 1959) Following the above steps, and in : presence of clinical evidence that the fracture d been reduced, the elbow was flexed as far as ssible without obliteration of the radial pulse, ually to 120°

During the initial stages of reduction, traction ıs carried out with the forearm in pronation /ainwright 1962) Towards the end of manipula- ın and before flexing the elbow, the forearm ıs abducted on the arm and brought into pination (Blount 1955)

In four patients (6 4 per cent), three of whom .d had manipulations twice previously, swelling the elbow rendered immediate reduction ıpossible Skin traction and elevation was applied r 48 hours after which reasonable reduction was :hieved by manipulation

ssessment of reduction

linically the fracture was considered reduced hen

a) The concavity seen on the posterior aspect of the elbow before reduction had disappeared
b) The elbow could be flexed to greater than a right angle without obliteration of the radial pulse
c) The "point" of the elbow was felt to lie in the line of the long axis of the humerus or even in front of it.
d) The epicondyles on the distal fragment were re-aligned with epicondylar ridges on the proximal one.

Radiologically the fracture was considered educed when all elements of displacement were orrected both in the anteroposterior (axial infero- uperior – Clarke 1964) and lateral views (Figure ·a and b)

ıssessment of the carrying angle

Clinically the carrying angle was considered 'estored when

a) The epicondyles were re-aligned with the epicondylar ridges of the proximal fragment.
b) The relation between the three bony prominences of the elbow, to the long axis of the humerus, as seen from behind with the elbow flexed, was comparable to that on the normal side ('The visual method of Smith" 1960) This indicates the position of the distal fragment in relation to the proximal one.

Radiologically, the carrying angle is restored when the cortices of the two fragments are continuous with each other in the absence of any rotation or angulation of the distal fragment

Fixation

Reduction was maintained by zinc oxide adhesive plaster, binding the flexed forearm to the arm just above the elbow A collar-and-cuff holds the elbow in the optimum position of flexion (Figure 5) The limb was then placed under the clothes to prevent the child from using his arm. This was continued for about 3 weeks. Flexion of the elbow was increased on the second or third day in patients who presented initially with grossly swollen elbows.

RESULTS

Assessment of results

The follow-up period ranged from 8 months to 6 years, the average time being 39 months.

a) *Clinically* – on completion of follow-up
   i) Excellent Normal appearance and function of the elbow joint with up to 5° change in the carrying angle and 5° limitation of extension
   ii) Good Change in the carrying angle of up to 5–10° but not beyond cubitus rectus, and up to 5–15° limitation of extension
   iii) Poor Any alteration in shape or function of the elbow greater than the above limits.
b) *Radiologically* – post-reduction X-rays.
   i) Excellent Correct anatomical alignment with no visible displacement.
   ii) Good No more than 3–4 mm lateral or posterior displacement, but with normal alignment
   iii) Poor Any rotation or angulation deformity persisting even if slight

Figure 4a Pre-reduction X rays, lateral and a p views

Figure 4b Example of excellent reduction, lateral and a-p views



re 5 Post reduction fixation Note the edge ie adhesive plaster has been partially divided

ical results

'he results after the most recent follow-up mination were excellent in 45 patients (73 8 cent) good in 11 (18 per cent) and poor in ' 2 per cent)

ll the vascular complications seen on the : examination improved and no ischaemic tracture resulted

'he neurological complications recovered ept in one patient where a pointing index ger deformity persisted

'ive patients developed sepsis at the site of icture of the skin by the lower end of the ximal fragment Two of these patients 'eloped osteitis at the fracture site

diological results

\t the time of the post-reduction X ray mination, there were excellent radiological ults in 40 patients (65 7 per cent), good in (19 7 per cent) and poor in 9 (14 6 per cent)

Redisplacement occurred in five patients (8 2 per cent) on the fourth or fifth day after reduction but was not sufficiently severe to justify remanipulation

The poor results

a) *Clinically* Two patients developed osteitis at the fracture site and ended up with an ankylosed elbow joint In the three other patients, the fracture had been manipulated more than once previously Varying degrees of cubitus varus were present One of these patients showed also hyperextension of the elbow due to uncorrected posterior displacement of the distal fragment In addition, one patient showed limitation of both flexion and extension of the elbow, the possible range of movement being 40°–110° One other patient showed limitation of the last 30° of extension.
b) *Radiologically* Of the nine poor results encountered, four had had previous attempts at reduction They presented grossly swollen elbows In two more patients, the swelling was so severe that flexion of the elbow to greater than a right angle was not possible and redisplacement occurred. In the remaining three patients, reduction was unstable, although swelling was not marked and residual displacement had to be accepted

DISCUSSION

In the treatment of any fracture, the objective is reduction into an anatomically acceptable and stable position without inflicting additional trauma In addition the method of reduction recommended should if possible be easy to apply and should not require prolonged stay in hospital In the treatment of supracondylar fracture of the humerus in children, closed manipulative reduction has been preferred to the other methods described in the literature Skin traction (Dunlop 1939) is

often inconvenient to the patient It may be difficult to apply in young children (Conwell & Reynolds 1961) and may result in distraction or over-riding with the resultant dangers (Staples 1959) Skeletal traction (Hart 1942) has the danger of infection of the pin tract, possible damage to the ulnar nerve (Wainwright 1962), and distraction at the fracture site (Staples & Hanover 1958) Open reduction may be complicated by infection and the incidence of joint stiffness is definitely higher than with other methods (Hammond 1952) In addition, these methods require a relatively longer stay in hospital than is necessary after closed manipulative reduction

The technique of closed manipulative reduction described by other authors consists of traction on the injured limb from the wrist against counter-traction from the axilla (Blount 1955) with the elbow straight (Charnley 1968) Sharrard (1971) advised traction with the elbow slightly hyperextended This however, proved to be unsafe as it was followed on occasions by rupture of the median nerve and injury to the brachial artery (Bristow 1923, Platt 1928) by the sharp edge of the distal end of the proximal fragment (Griffiths 1968) These disadvantages are obviated if manipulation is carried out with the elbow flexed 40°–60° This technique has other advantages also Reduction of the posterior displacement is easier by this method as the posterior structures ("the posterior hinge") only are tightened The tissues in front of the elbow remain lax and give way in front of the distal fragment whilst it is moulded forward by the tightening posterior hinge It allows maximum traction to be effected at the site of the fracture without subjecting the neurovascular bundle to overstretching Unlike manipulation in extension, during which the surgeon has to lean backward to effect maximum pull, he leans forward during manipulation in flexion This enables him to maintain traction with one hand whilst manipulating the fracture with the other hand, thus the need for a second assistant is obviated

Immobilization is carried out with a collar-and-cuff or broad sling with the elbow Jones' position In this way the forearm exposed for observation of the radial pulse is also more convenient than the methods described in the literature application of zinc oxide adhesive p about the elbow (Figure 5) and pu limb under the child's clothing are parti useful in difficult children As sligh placement occurred in only five patien per cent), and did not require it is concluded that the method is sa effective Zinc oxide adhesive plaster applied must not encircle the limb comp and it is preferable to partially divide it edge to avoid cutting into the skin (Fig

The use of the Jones' position has blamed for inadequate assessment restoration of the carrying angle important to realize that the carrying a best restored and maintained by ach accurate reduction The impingement cortices of both fragments indicates maintains reduction, and hence the ca angle Restoration of the carrying angle assessed with the elbow flexed when th re-alignment of the epicondyles wit epicondylar ridges and by the Smith method (Smith 1960) The Jones' positio provides "the natural splint position" the tightened posterior hinge moulds condylar fragment in place and diminish possibility of redisplacement

Conclusions

1) Manipulation of supracondylar fractu the humerus by traction on the forearm the elbow flexed 40°–60° avoids stretchin the neurovascular bundle across the distal of the proximal fragment It also facilit reduction

2) The carrying angle is best restored maintained by achieving accurate reducti With the elbow flexed, it can be judged the re-alignment of the epicondyles with epicondylar ridges and the visual meth described by Smith (1960)

3) A collar-and-cuff with the elbow in

position provides an efficient and easy of fixation of the reduced supra- ar fracture

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RENCES

W (1955) Injuries about the elbow In :tures in children, pp 26–42. Williams and tins Co, Baltimore

r, W R. (1923) Myositis ossificans and tmann's paralysis. Notes on two cases trating the rarer complication of supra- lylar fracture of the humerus. *Brit J Surg* 475

ty, J (1968) *The closed treatment of mon fractures* Third edition. pp 105–114 nd S Livingstone, Edinburgh and London.

. K. C (1964) *Positioning in radiography* hth edition, p 36 Heiman Medical Books , London.

ll, J & Reynolds, F C (1961) Complete tures of the lower end of the humerus. In *and Conwell's management of fractures, locations and sprains* Seventh edition, pp –544 Kimpton, London.

Dunlop, J (1939) Transcondylar fractures of the humerus in childhood. *J Bone Jt Surg* **21**, 59–73

Griffiths, D Ll. (1968) Hazards of closed reduction of fractures. *Texas Med* **64**, 46–50

Hammond, G (1952) Symposium on orthopaedic surgery and neurosurgery Management of supracondylar fractures of the humerus in children. *Surg Clin N Amer* **32**, 747–762.

Hart, V L. (1942) Reduction of supracondylar fracture in children *Surgery* **11**, 33–37

McLaughlin, H L. & Stimson, B B (1959) Injuries of the elbow In *Trauma*, pp 208–211 W B Saunders Co, Philadelphia and London.

Platt, H (1928) On the peripheral nerve complications of fractures and dislocations of the elbow In *Robert Jones Birthday Volume* Ed Milford, H pp 195 Oxford University Press.

Sharrard, W J W (1971) *Paediatric orthopaedics and fractures*, pp 946–1956 Blackwell Scientific Publications, Oxford and Edinburgh

Smith, L. (1960) Deformity following supracondylar fracture of the humerus. *J Bone Jt Surg* 42-A, 235–252.

Staples, O S (1959) Complications of traction treatment of supracondylar fracture of the humerus in children *J Bone Jt Surg* 41-A, 369–370

Staples, O S & Hanover, N H (1958) Supracondylar fracture of the humerus in children. *J Amer med Ass* **168**, 730–734

Wainwright, D (1962) Fractures involving the elbow region In *Modern trends in orthopaedics -3- Fracture treatment* Ed. Clarke, M P J pp 211–243 Butterworths, London.

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COTREL TRACTION, EXERCISES, CASTING IN THE TREATMENT OF IDIOPATHIC SCOLIOSIS

A Pilot Study and Prospective Randomized Controlled Clinical Trial

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A pilot study of ten individuals with adolescent-onset idiopathic *demonstrated that a week of Cotrel traction and exercises* did not [illegible] curve correction obtained by the application of an elongation, flexion (EDF) cast. There was *however, a significant improvement* [illegible]

Key words scoliosis traction, exercises casts, lateral bending

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The scoliosis treatment team in this centre was impressed by the management of scoliosis as demonstrated by Cotrel & Morel (1964) when they visited Berck Plage Subsequently Cotrel visited Louisville and demonstrated his technique of traction, exercises, and casting (elongation, derotation, flexion-EDF) Since then we have used this method for the non-operative treatment of idiopathic scoliosis but have been disappointed with the long-term results. Furthermore it is time-consuming in terms of manpower and hospitalization

Nachemson & Nordwall (1976, 1977) demonstrated that *Cotrel traction is of no* value in the preoperative phase of treatment of idiopathic scoliosis Their patients did not achieve a better operative correction of their curve nor did any benefit in terms of safety accrue when surgery was preceded by a week of traction Ramsay et al (1976) have shown that with Cotrel traction curve correctio[illegible] be obtained but that no further impro[illegible]

[illegible]

"loosening-up" exercises, or indeed [illegible] responsible for curvature correction. A [illegible] study and a prospective randomized con[illegible] clinical trial were therefore carried out.

PILOT STUDY

Patients and method

Ten consecutive patients with adolesce[illegible] idiopathic thoracic scoliosis were [illegible] There were nine females and one male. The [illegible] age was 12 9 years. They underwent our [illegible] patient treatment programme of tractio[illegible] physical therapy exercises and were EDF ca[illegible] the eighth day after admission. Traction wa[illegible]

f autoelongation and these individuals were aged to perform this throughout the day At the traction was altered to fixed traction g with 5 lb rising to 12 lb on their seventh Physical therapy exercises were performed in mnasium for two 1-h periods each day the supervision of a physical therapist In ssion 20 exercises were performed 15 times succession and the various exercise routines trated on lateral bending correction of the nd pelvic tilting to mobilize the concomitant lordosis. On the eighth day an EDF cast pplied under maximum tolerable fixed 1. In order to control the investigation these uals were similarly EDF casted on day 1 treatment was commenced. This cast was moved in order that they could go through atment regime

nes of antero-posterior (AP) radiographs of ne were taken during the treatment period curves were measured by the Cobb method 1948). The variables studied were

iding curve before treatment
ve on lateral bending before treatment
iding curve in first cast, before treatment
ve on lateral bending before second cast.
ve under maximum traction before second

iding curve in second cast, after treatment

s

mean magnitude of deformity during ng before treatment was 43°, on lateral g before treatment 20°, and standing in first cast 26° Table 1 shows the of traction and exercises on the standing in the cast, and on lateral bending was no significant difference between rve measurements in the casts on day 1 ay 8, 26° and 26° ($P>0.05$) Lateral g corrected the curve from 20° to 13°, a ically significant correction at the 0 1 per evel In no case did the maximum n correction equal or better the tion determined by initial lateral

Table 1 Results of pilot study

	1	2	P
ng curve in cast	26°	26°	>0 05
on lateral bending	20°	13°	<0 001

bending, and cast correction was significantly worse than the maximum traction correction ($P<0.05$)

Comment

From this pilot study it was considered that 8 days of hospitalization for traction and physical therapy was not justified if a policy of EDF casting was to be pursued, as no benefit in terms of curve correction in the cast occurred from such a treatment regime However, it appeared that treatment had improved the lateral bending correction significantly and considerably As the maximum traction correction after treatment did not even approach the initial lateral bending correction, physical therapy exercises seemed to be the most likely cause of the improvement in lateral bending correction A prospective, randomized, controlled clinical trial was therefore carried out

PROSPECTIVE, RANDOMIZED, CONTROLLED CLINICAL TRIAL

Patients and method

The next 20 patients with a diagnosis of adolescent onset idiopathic scoliosis were randomly allocated to one of two treatment groups

1 Traction and no exercises
2. Exercises and no traction.

Traction or exercises were performed as in the pilot study

The mean age of the two groups of patients did not differ significantly, 13 1 years and 13 6 years ($P>0.05$) nor did mean curve magnitude before treatment, 42° and 40° ($P>0.05$) The same variables were studied in these groups as in the original pilot study

Results

1 *Traction only* Table 2 shows the effect of traction on the standing curve in the cast and the curve on lateral bending There was no significant difference between the cast measurements on day 1 and day 8, 32° and 35°, respectively ($P>0.05$) Nor was there any

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COTREL TRACTION, EXERCISES, CASTING IN THE TREATMENT OF IDIOPATHIC SCOLIOSIS

A Pilot Study and Prospective Randomized Controlled Clinical Trial

*ROBERT A. DICKSON & KENTON D LEATHERMAN

Kosair Spine and Scoliosis Treatment Center, Kosair Hospital,
982 Eastern Parkway, Louisville, Kentucky, USA.

A pilot study of ten individuals with adolescent-onset demonstrated that a week of Cotrel traction and exercises did no [illegible]

clinical trial showed that the exercise programme and not the responsible for rendering the spine less rigid

Key words scoliosis, traction, exercises, casts, lateral bending

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The scoliosis treatment team in this centre was impressed by the management of scoliosis as demonstrated by Cotrel & Morel (1964) when they visited Berck-Plage Subsequently Cotrel visited Louisville and demonstrated his technique of traction, exercises, and casting (elongation, derotation, flexion-EDF) Since then we have used this method for the non-operative treatment of idiopathic scoliosis but have been disappointed with the long-term results. Furthermore it is time-consuming in terms of manpower and hospitalization.

Nachemson & Nordwall (1976, 1977) demonstrated that Cotrel traction is of no value in the preoperative phase of treatment of idiopathic scoliosis. Their patients did not achieve a better operative correction of their curve nor did any benefit in terms of safety accrue when surgery was preceded by a week of traction. Ramsay et al. (1976) have shown that with Cotrel traction curve correct be obtained but that no further impro is achieved after 8 days Physical thera integral part of this treatment program it is not clear whether the tract "loosening-up" exercises, or indeed bo responsible for curvature correction. A study and a prospective randomized clinical trial were therefore carried out.

PILOT STUDY

Patients and method

Ten consecutive patients with adolesce idiopathic thoracic scoliosis were inter There were nine females and one male. The age was 12.9 years. They underwent our us patient treatment programme of tracti physical therapy exercises and were EDF ca the eighth day after admission. Traction wa

ta orthop scand. 49, 49–53, 1978

)NTANEOUS REGRESSION OF A
LIGNANT PRIMARY BONE TUMOUR

:R DISSING, JAN HEERFORDT, TORBEN SCHIØDT
TTO SNEPPEN

[illegible]

up

Key words osteosarcoma, chondroblastoma, bone tumour, spontaneous regression

Accepted 17 viii 77

literature contains very few reports of rently spontaneous regression of histo-:ally confirmed malignant tumours idering that' malignant primary bone ours make up only 0 5 per cent of all gnant tumours, cases of spontaneous ssion in this group of tumours are of se extremely rare To our knowledge, only t are on record (Everson & Cole 1966)

:E REPORT

-year-old man was first seen in February 1971 [illegible]

ition was good, and except for mild atrophy of nuscles of the left thigh and a limp, physical unation showed no abnormalities. Radio-hy disclosed a widespread osteolytic lesion in eft half of the pelvis (Figure 1). Chest radiography was normal ESR was 100 mm and alkaline phosphatase was slightly elevated. Open biopsy was done at the anterior demarcation of the tumour in the iliac bone It showed – as did subsequent revisions of the same preparations – benign chondroblastoma (Figure 2a). In view of the clinical and radiological findings, however, this diagnosis did not seem convincing Therefore, an exploratory operation through a wide posterior approach was performed in March 1971 In the iliac bone there was a tumour about 12 × 8 × 8 cm, anteriorly involving the superior ramus of the ischium and posteriorly the sacro-iliac joint and the lateral mass of the sacral bone Ample tumour tissue was excised for histological examination which showed – as did subsequent histological revisions of these preparations – a malignant, primary bone tumour, [illegible]

therapy, the patient received only symptomatic treatment, viz, non-weight-bearing and analgesic medication

Figure 1 Primary radiography, in January 1971, showed an osteolytic tumour involving the [illegible] *ramus of the ischium as well as the ilium, from the sacroiliac joint proximally to the acetabulum* [illegible]

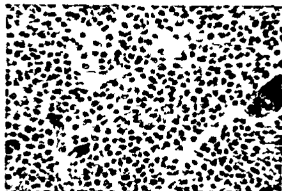
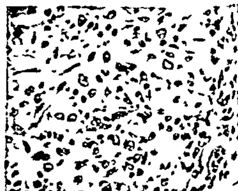


Figure 2a First biopsy Cellular tumour tissue with scattered giant cells suggestive of osteoclasts The tumour cells are small and uniform, with distinct cell borders Interpreted as a benign chondroblastoma. ×*350*



b Second biopsy A more polymorphous appe[illegible] *with more ample intercellular substance and* [illegible] *giant cells The tumour cells show variations* [illegible] *shape, size, and chromatin content of the* [illegible] *Cell borders indistinct In places the interc*[illegible] *substance shows the nature of osteoid* [illegible] *Interpreted as* osteosarcoma *or a* [illegible] chondroblastoma. ×*350*



ture 3 Radiography in May 1972 revealed progression of the tumour with extensive destruction volving the sacrum and the majority of the acetabulum

Over the next few years the patient, still treated, was followed up in the outpatient clinic ntil the spring of 1973 his condition deteriorated adily The regional pain grew worse and now he o had rest pain. The left leg became 2 cm shorter d the difficulty in walking increased, cessitating the use of two English canes. Radio- aphic examinations during this period showed creasing destruction of the left half of the pelvis igure 3). But in the course of the latter half of 73 a [illegible]

clinical improvement a radiological remission ok place The tumour area became increasingly limited and sclerosed (Figure 4) When last seen March 1977 the patient was feeling perfectly well. There have not at any time been signs of dis semination of the tumour, in particular not to the lungs.

DISCUSSION

Everson & Cole, in 1966, collected the cases of apparently spontaneous remission of histo- logically confirmed malignant tumours from the available literature Among these tumours were eight primary bone tumours, including four osteosarcomas (one of these four cases has also been described by Levin in 1957) Everson & Cole themselves use the term cases of possible spontaneous regression ,



Figure 4 In March 1977 the radiological remission is unmistakable The tumour area is well-def increased sclerosis

implying that reports of an apparently spontaneous remission of a histologically confirmed malignant tumour should be regarded with scepticism and diagnostic criteria should be very strict

In the present case the most recent clinical and radiological follow-up examination was performed 9 years after the onset of symptoms, 6 years after the biopsies, and 4 years after the time at which bony destruction was radiologically at a maximum The second biopsy showed a primary bone tumour having definite malignant features (Figure 2b) Exact classification was less certain It might be either a rare case of malignant chondroblastoma (McLaughlin et al 1975, Riddell et al 1973, Sirsat & Doctor 1970) or – more probably – a highly differentiated chondro-

blastic osteosarcoma Thus, apparently a case of clinical and radiological, spont remission of a bone tumour which hac classified as undoubtedly malignant acc to both radiological and histological fin

Stewart (1952) has discussed the possible causes of spontaneous remissio hypersensitivity reactions, haemorrhage tumour, and a reaction to the tumour pr Immunological factors have been mentio a cause of spontaneous regression of mal tumours. However, O'Hara et al. (1968 not find any known specific, immunol factors which could explain the lo survival, in particular with osteosarcoma. concluded that other host-tumour rel must be operative in the defence mech Woodruff (1969) has reported the appea

comas in relation to immunosuppressive
py In the patient reported above we
ot suggest any reason whatsoever for why
emission took place

ERENCES

son, T C & Cole, W H (1966) Spontaneous egression of sarcoma of the bone In *Spontaneous regression of cancer*, pp 357–385 Saunders Comp, London
in, E J (1957) Spontaneous regression (cure?) of a malignant tumor of bone *Cancer* 10, 377–381
Laughlin, R E, Sweet, D E, Webster, T & Merritt, W M (1975) Chondroblastoma of the pelvis suggestive of malignancy *J Bone Jt Surg* 57-A, 549–551
O'Hara, J M, Hutter, R V P, Foote, F W, Miller, T & Woodard, H Q (1968) An analysis of thirty patients surviving longer than ten years after treatment for osteogenic sarcoma *J Bone Jt Surg* 50-A, 335–354
Riddell, R J, Louis, C J & Bromberger, N A (1973) Pulmonary metastases from chondroblastoma of the tibia. Report of a case. *J Bone Jt Surg* 55-B, 848–853
Sirsat, M V & Doctor, V M (1970) Benign chondroblastoma of bone. Report of a case of malignant transformation. *J Bone Jt Surg* 52 B, 741–745
Stewart, F W (1952) Experiences in spontaneous regression of neoplastic disease in man *Tex Rep Biol Med* 10, 239–253
Woodruff, Sir M (1969) The challenge of cancer-sarcoma *Ann roy Coll Surg Engl* 44, 299–307

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A PHOTOELASTIC STUDY OF A MODEL OF THE PROXIMAL FEMUR

A Biomechanical Study of Unstable Trochanteric Fractures I

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Gentofte Hospital, Hellerup, Denmark

In an attempt to standardize an experimental model for biomech studies of unstable trochanteric fractures, acrylic models of the pr femur were investigated by the photoelastic technique By matchin stress distribution in the acrylic models to those calculated by Pauw was found that the optimal femoral shaft and resultant hip joint force were 5° and 6° to the vertical, respectively The abductor muscle determined to be 55 per cent of the resultant hip joint force at 15° inclination to the vertical.

Key words biomechanics, femoral neck, joint forces

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Wolff (1870) described the architecture of the trabecular system in the femoral neck as being in accordance with the mathematical stress trajectories. A number of papers concerning the transmission of forces from the hip joint to the femoral shaft have confirmed his theories (Backman 1957, Inman 1947, Koch 1917, Tobin 1955, Williams & Svensson 1971) either through mathematical calculations or in laboratory investigations on cadaveric bone

Pauwels (1935) introduced a simple mathematical analysis of the force vectors around the hip joint in order to calculate the load on the femoral head. Several more recent papers have discussed the magnitude and direction of the hip joint force and the abductor muscle force as well as the inclination angle of the femoral shaft Somewhat conflicting results have been stated, however, concerning the relationships between these variables.

The aim of the present studies is to the mechanical behaviour of differ nail-plates in osteosynthesis of trochanteric fractures For this pu however, a standardized experimental ment is needed as regards the inc angles of the femoral shaft, the hip joi and the abductor muscle force, as well relation between the magnitudes of th forces. To simplify the static exper these variables will be considered in the plane only

The photoelastic technique (Foppl & 1972) has been widely used by engineers analysis of constructions which are dif describe in mathematical terms. Brek al (1972) mentioned this method as useful in determining the mechanical viour of bone, although the aniso bone was not taken into account. The elastic technique has been applied

els (Fessler 1957, Milch 1940, Ruszkowski Iuftic 1972) showing stress patterns coronding with the stress trajectories in the oral neck (Wolff 1870, Koch 1917, Pauwels 5, 1973)

he present paper will present the results of photoelastic technique applied to twoensional models of the proximal femur to a standardized experimental model with rence to the parameters mentioned

TERIALS AND METHODS

toelasticity (Foppl & Monch 1972) is based on fact that some transparent, isotropic solids ome bi refringent under mechanical load For erimental purposes an exact model of the struction is made from a photoelastic material Araldite-B®). The model is loaded and minated with polarized light in a polariscope difference between the principal stresses at any point in the model is proportional to the relative retardation of the two component rays of polarized light that pass through the point When the relative retardations are equal to an integral multiple of the wavelengths of the light used, no light is transmitted In monochromatic polarized light the lines of constant shear stress appear as black bands – the isochromates In white polarized light the neutral axis, which is stress free, is seen as a dark band, while the isochromates appear in the colours of the spectrum. The isochromates are numbered (i e ordered) from the neutral axis which is called the zero-isochromate The number of isochromates thus increases with increasing mechanical stress.

Based on measurements made on X-rays of normal hip joints from five patients, two-dimensional models of the proximal femur were manufactured in polyester (Araldite-B®) An idealized model with a femoral neck angle of 130° and one of 140° were made

The model was fastened to a steel socket and placed in the polariscope (Tiedemann A 159, W Germany) The model was loaded vertically (Figure 1) by a steel bar (weight = 6 8 Newton) supplemented with a load proving ring (Tiedemann H 256 M, W Germany) weighing 3 2 N, on which a screw press was applied – the total load being

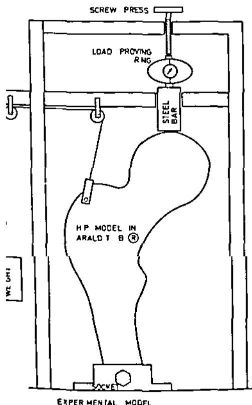


Figure 1 Experimental arrangement

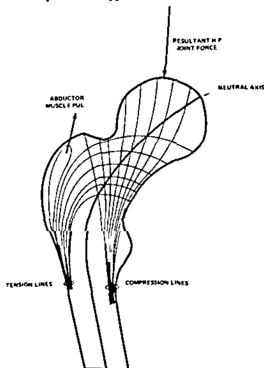


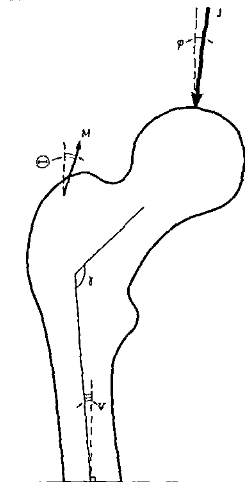
Figure 2 Reconstruction of stress trajectories (Koch 1917, Pauwels 1973)

the greater trochanter of the model The model was viewed in polarized light and the picture on the analyzer screen was photographed and compared to the stress trajectories (Figure 2) reconstructed from Koch (1917) and Pauwels (1935 1973)

The force vectors and the inclination angles are shown in Figure 3

In the experimental series the parameters were varied as follows, although corrections were made according to the vertical loading of the models

ψ = femoral shaft inclination 5°, 10°, 15°
φ = hip joint force inclination 6°, 11°, 16°
Θ = abductor pull direction 10°, 15°, 20°
$\frac{M}{J}$ = $\frac{\text{abductor muscle force}}{\text{hip joint force}}$ 0 55, 0 60 0 65



FORCES AT THE PROXIMAL FEMUR

J RESULTANT HIP JOINT FORCE φ JOINT FORCE INCLINATION
M = ABDUCTOR MUSCLE FORCE Θ ABDUCTOR PULL INCLINATION
γ FEMORAL NECK ANGLE ψ FEMORAL SHAFT INCLINATION
DOTTED LINES INDICATES VERTICAL

Figure 3 Forces at the proximal femur

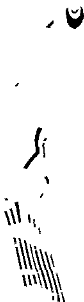
These figures represent average values f papers referred to in the discussion.

RESULTS

Sixty-five experiments were , the 140° femoral neck model experiments on the model with a 130° neck angle Examination of the from the experiments on both model that the optimal arrangement with the parameters *mentioned* consiste femoral shaft inclination (ψ) of combination with a joint force of 6° and an abductor pull inclinatio 15° The magnitude of the abductor force (M) was determined to be 55 the resultant hip joint force (J) These were chosen as the stress patterns in (Figure 4 and Figure 5) correspond with the stress trajectories shown in F Stress patterns not corresponding t trajectories were rejected, as demonst Figure 6 (ψ=15°, φ=11°, θ M/J – 0 55)

In this series of experiments the in of an increased femoral shaft inclinat and an increased joint force inclinat were similar Both displaced the neut laterally (Figure 6) and with in inclination of the model, the stress patt the medial part of the neck and shaf changed from compression to t (Figure 7)

The direction (Θ) and magnitude abductor muscle pull in relation to the force (M/J) did not show any great eff the stress patterns in the model In this Θ was determined as 15° and M/J as Altering the abductor pull direction to θ displaced the neutral axis slightly la and Θ=20° involved a slight increase o number of isochromates in the medial pa the shaft Increasing the abductor muscle in relation the resultant hip joint increased the bending moment and disp the neutral axis slightly in the lateral dire



ıre 4 Normal hip model 130° femoral neck ɫe

5°, φ=6°, Θ=15°, M/J=0 55



Figure 5 Normal hip model 140° femoral neck angle

ψ=5°, φ=6°, Θ~15°, M/J=0 55

ƷCUSSION

ʼo-dimensional studies of hip models have ɲ carried out using the photoelastic hnique (Haboush 1952, Milch 1940, ˬ 1951, Ruszkowski & Muftic 1972) 1 the method has been considered useful in ɔerimental research by Brekelmans et al ʼ72) A three-dimensional photoelastic ɦnique was introduced by Hetenyi (1939) d has also been applied to hip models ɛssler 1957, Williams & Svensson 1971) us technique is however much more mplex and has not contributed an increase information (corresponding with the com- ɛxity) as compared with the rather simple ʼo-dimensional technique, both methods vealed stress patterns corresponding to olff's trajectories (Fessler 1957, Milch 1940, uszkowski & Muftic 1972)

In the present study it has been the author's aim to consider the force vectors and the femoral shaft inclination in a two-dimensional static study in the frontal plane, as this is the most practical arrangement for further laboratory investigations. It is obvious that the results obtained can not directly be used clinically as the eccentric position of the centre of gravity, the muscle pull from the thigh muscles, the forces of the ligaments and the anteversion of the femoral neck were not considered The shear stresses are higher in the central plane in the model than average because of the isotropy of the model material In the experiments the influences of deformations of the model and probable shear forces from torque were not taken into account, but were assumed not to alter the stress patterns.

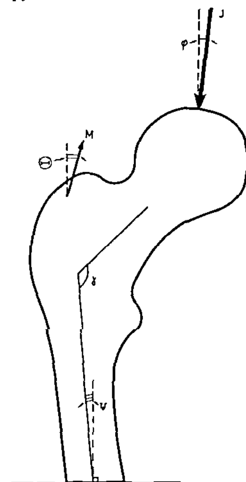
Accepting the obvious limitations of the technique and the experimental arrangement, the author has found it worthwhile to determine an optimal model with reference to

equivalent to the resultant hip joint force (J) The abductor muscle pull was applied by weights (=70 N) over a system of pulleys to a hole drilled in the greater trochanter of the model The model was viewed in polarized light and the picture on the analyzer screen was photographed and compared to the stress trajectories (Figure 2) reconstructed from Koch (1917) and Pauwels (1935, 1973)

The force vectors and the inclination angles are shown in Figure 3

In the experimental series the parameters were varied as follows, although corrections were made according to the vertical loading of the models

ψ – femoral shaft inclination 5°, 10°, 15°
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Θ = abductor pull direction 10°, 15° 20°
$\frac{M}{J} - \frac{\text{abductor muscle force}}{\text{hip joint force}}$ 0 55, 0 60 0 65



FORCES AT THE PROX MAL FEMUR

J RESULTANT H P JO NT FORCE
M ABDUCTOR MUSCLE FORCE
γ FEMORAL NECK ANGLE
φ JO NT FORCE NCL NATION
Θ ABDUCTOR PULL INCLINAT ON
ψ FEMORAL SHAFT INCL NATION

DOTTED LINES NO CATES VERT CAL

Figure 3 Forces at the proximal femur

These figures represent average values from papers referred to in the discussion

RESULTS

Sixty-five experiments were
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Stress patterns not corresponding t
trajectories were rejected, as demonst
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number of isochromates in the medial p
the shaft Increasing the abductor muscl
in relation the resultant hip joint
increased the bending moment and disp
the neutral axis slightly in the lateral direc

gnitude of the abductor muscle pull was etermined to be 55 per cent of the resultant p joint force in accordance with the results of other studies (McLeish & Charnley 1970, auwels 1935, Rydell 1966, Williams & vensson 1968) In conclusion, the author onsiders the standard experimental gement described, as found through hotoelastic studies, to be acceptable and very seful for further laboratory investigations of ie unstable trochanteric fracture

CKNOWLEDGMENTS

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EFERENCES

mtmann, E & Kummer, B (1968) Die Beanspruchung des Menschlischen Huftgelenks *Z Anat. Entwickl.-Gesch* **127**, 286–314

ackman, S (1957) The proximal end of the femur *Acta radiol. (Stockh),* Suppl. 146

rekelmans, W A. M , Poort, H W & Slooff, T J J H (1972) A new method to analyse the mechanical behavior of skeletal parts. *Acta orthop scand* **43**, 301–317

enham, R A (1959) Hip mechanics. *J Bone Jt Surg* **41 B**, 550–557

essler, H (1957) Load distribution in a model of the hip joint. *J Bone Jt Surg* **39 B**, 145–153

oppl, L & Monch, E. (1972) *Praktische Spannungsoptik*, III Auflage, Springer, Berlin, Heidelberg New York.

laboush, E. J (1952) Photoelastic stress and strain analysis in cervical fractures of the femur *Bull Hosp Jt Dis (N Y)* **13**, 252–258

Hamacher, P & Roesler, H (1972) [illegible]

Hetenyi, M (1939) The application of hardening resins in three-dimensional photoelastic studies. *J appl. Physics* **10**, 295–300

Inman, V T (1947) Functional aspects of the abductor muscles of the hip *J Bone Jt Surg* **29**, 607–619

Koch, J C (1917) The laws of bone architecture *Amer J Anat.* **21**, 177–298

McLeish, R. D & Charnley, J (1970) Abduction forces in one-legged stance *J Biomech* **3**, 191–209

Milch, H (1940) Photoelastic studies of bone forms. *J Bone Jt Surg* **22**, 621–626

Pauwels, F (1935) *Der Schenkelhalsbruch – ein mechanisches Problem* Ferdinand Enke, Stuttgart.

Pauwels, F (1951) Uber die Bedeutung der Bauprinzipen des Stutz und Bewegungsapparates fur die Beanspruchung der Rohrenknochen *Acta anat (Basel)* **12**, 207–227

Pauwels, F (1973) *Atlas zur Biomechanik der gesunde und kranken Hufte* Springer, Berlin, Heidelberg, New York.

Ruszkowski, I & Muftic, O (1972) Biomechanische Erklarung der Etiopathogenesis von Knochenaposition am Hals des Femur bei Coxarthrose. *Arch orthop Unfall Chir* **73**, 80–88

Rydell, N W (1966) Forces acting on the femoral head prosthesis. *Acta orthop scand.*, Suppl. 88

Tobin, W J (1955) The internal architecture of the femur and its clinical significance *J Bone Jt Surg* **37-A**, 57–72.

Williams, J F & Svensson, N L. (1968) A force analysis of the hip joint *Bio-med Engng* **3**, 365–370

Williams, J F & Svensson, N L (1971) An experimental stress analysis of the neck of the femur *Med biol. Engng* **9**, 479–493

Wolff, J (1870) Uber die innere Architectur der Knochen und ihre Bedeutung für die Frage von Knochenwachsthum. *Virchows Arch. path Anat* **50**, 389–450

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Figure 6 Rejected stress patterns

$\psi = 15°, \varphi = 11°, \Theta = 20°, M/J = 0\ 55$

Stress patterns not in accordance with Wolff's trajectories. Neutral axis displaced laterally The isochromates are tension lines in the medial part of the shaft There is practically no bending in the neck.



Figure 7 Rejected stress patterns

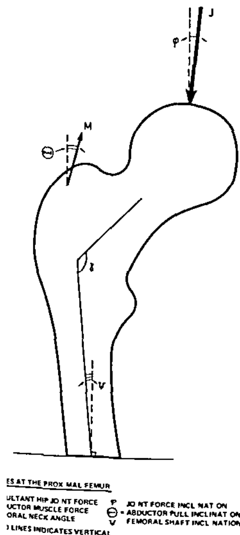
$\psi = 15°, \varphi = 16°, \Theta = 15°, M/J = 0\ 65$

Neutral axis is the most laterally situated lin[e] isochromates in the medial part of the ne[ck] shaft are all tension lines demonstrating [a] bending moment

the aforementioned parameters, as variations of these showed considerable changes in the stress trajectories (Koch 1917, Pauwels 1935, 1973, Wolff 1870) During the past 40 years many attempts have been made to determine the force vectors around the hip joint and somewhat conflicting values have been reported for the femoral shaft inclination (ψ), the resultant hip joint force (J) and its inclination (φ) and the abductor muscle pull (M) and its acting direction (Θ), as well as the relations between the magnitudes of the two forces

Prior to the present study, calculations were made from values stated in previous papers considering all these variables in studies of the static one-legged stance Calculated values of M/J varied from 0 40–0 60 (McLei[sh] Charnley 1970, Pauwels 1935, Rydell [1] Williams & Svensson 1968) to 0.65– (Amtmann & Kummer 1968, Denham [1] Hamacher & Roesler 1972, Inman 194[7] the same studies the joint force inclinati[on] has been reported as being between 6° [and] 17° and the abductor pull direction between 10° and 21°, while the femoral [shaft] inclination (ψ) has been stated as b[e] between 5° and 15°

In this series the femoral shaft inclin[ation] was determined to be 5° in accordance [with] Pauwels (1935). The joint force inclin[ation] was found to be 6° and the direction of [the] abductor muscle pull to be 15°, which co[rresponds] well with McLeish & Charnley (1970) ...



e 1 Forces at the proximal femur

:scription given in the previous paper (Jensen . This included loading of the model in a :scope with simultaneous application of ctor muscle force The femoral shaft ation (ψ) was 5°, the joint force inclination , the abductor pull direction (Θ) 15° and the itude of the abductor pull (M) was 55 per cent : joint force (J) (Figure 1). Lines of constant stress in the nail-plate, the isochromates, were ered from the centrally placed neutral axis in stal 3 cm of the nail and the proximal 3 cm of ate before the connection to give the order of ochromates.

e models of the nail-plates were loaded in the al position and at 11° inclination to the vertical to clarify the influence of the femoral shaft inclination ($\psi = 5°$) and the inclination of the hip joint force ($\varphi = 6°$)

The osteosynthesis models of the unstable trochanteric fracture were loaded at 11° inclination, with the hip joint force amounting to 15 0 Newton. In order to clarify the influence of the abductor muscle force this was applied with 15° inclination and amounted to 55 per cent of the hip joint force (=8 25 Newton)

Table 1 Order of isochromates according to nail plate angle

Nail plate angle	Order in nail	Order in plate
125°	5 0	6 5
135°	4 5	5 5
140°	4 0	5 0
150°	3 5	4 5
160°	3 0	3 5

The values stated are average values.
The order in the nail is counted 3 cm proximal to the connection between nail and plate and the order in the plate 3 cm distal to the connection.

RESULTS

Twenty experiments were performed with the nail-plate models and 47 experiments with the osteosynthesis models of the unstable trochanteric fracture without medial support.

Table 1 demonstrates that an increase of the angle between the nail and the plate significantly reduced the order of isochromates ($P < 0\ 0005$, Kruskall-Wallis test)

The maximum shear force (τ_{max}) in the model of the nail can be expressed by the equation (Foppl & Monch 1972)

$$(1)\quad \tau_{max} = \frac{S}{0\ 2 \times d} \times \delta$$

(S = photoelastic constant, which for Araldite-B® = 1 0 N/mm², d = thickness of model = 10 mm, δ = order of the isochromates). For the current experiments the equation will thus be

$$(2)\quad \tau_{max} = 0.5 \times \delta\ \text{N/mm}^2$$

The order of isochromates in the distal part of the nail of a 125° nail plate (Figure 2) was

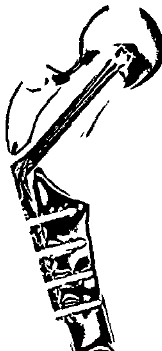


Figure 2 Stress patterns in a 125° nail-plate The thin interrupted centerline is the neutral axis (=zero-isochromate) The isochromates are numbered from the neutral axis In the distal part of the nail near to the connection with the plate five isochromates can be counted

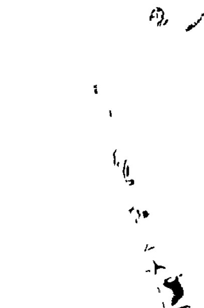


Figure 3 Stress patterns in a 150° nail ... the distal part of the nail near the ... the plate 3 5 isochromates can be ... side of the centrally placed neutral axis

found to be 5 0 (Table 1) The maximum shear stress is thus calculated as

$$\tau_{max\ 125°} = 0.5 \times 5.0 = 2.5\ N/mm^2$$

For a 150° nail-plate (Figure 3) the order of isochromates was 3 5 (Table 1) and the maximum shear stress is calculated as

$$\tau_{max\ 150°} = 0.5 \times 3.5 = 1.75\ N/mm^2$$

The reduction in shear stress is thus about 30 per cent by using the 150° nail-plate as compared with the 125° nail-plate As seen from Table 1 the order of isochromates and thereby the maximum shear stress is even [illegible]

considerably larger in this area ... ments on the osteosynthesis model demonstrated that the abductor m... increased the shear forces. The ... isochromates was 0 5–1 0 higher ... abductor pull was applied to the ... compared to the situation where the ... force was acting separately

The experiments on the nail-pla... demonstrated that loading the model ... inclination of 11° to the vertical, ... ponding to a femoral shaft inclination ... and a joint force inclination of 6°, red... order of isochromates by 0 5–1.5 in the ... part of the nail and by 1 0–2.0 in the p... part of the plate as compared with the ... ment with the plate positioned vertically

USSION

biomechanical experiments on medial al neck fractures (Haboush 1952, 1953, :y et al. 1959, Spotoft 1949) it is known steeper placement of the nail reduces the on the nail and thereby increases the anical strength of the osteosynthesis. :el (1963), however, pointed out the tance of considering also the trabecular ture and the mechanical properties of the

the unstable trochanteric fracture ut medial support the nail-plate alone mits the entire load from the femoral to the femoral shaft. Sarmiento (1963) nmended a steep placement of the nail rochanteric fractures to reduce the anical load on the implant Some authors :er 1958, Grover 1966, Martz 1956) ioned that the connection between the and the plate was the weak point in the truction and thus the most susceptible to anical failure

ie photoelastic technique used in this s has its obvious limitations (Jensen) The stress patterns are for instance only idered in the frontal plane, and rmation of the model is assumed not to the stress patterns. The model is idered free from sagittal forces.

the rather simple mathematical cal- tions given in this paper the maximum r stress in the distal part of the nail of a nail-plate was found to be 2 5 N/mm² n the model was loaded with 15 0 N In parison, the maximum shear force in the of a 150° nail-plate was calculated as 1 75 nm² From Paul's studies (1967) it is wn that the human hip joint is exposed to es of about six times the body weight in mal level walking

rather simple calculation can be made n the experimental values to estimate the ro shear forces on the Jewett nail for each a woman of 60 kg (≈589 N) takes during lking The maximum shear stress in a 125° l-plate would thus be calculated to be /15 0 × 589 × 6 = 589 N/mm² In a similar situation applying a 150° nail-plate the maximum shear stress amounts to 1 75/15 0 × 589 × 6 = 412 N/mm², which is only 70 per cent of the stress on the 125° nail-plate As the hip is exposed to cyclic loading during walking the implant has to absorb a considerable amount of energy during the time of fracture union. The risk of implant failure due to metal fatigue increases with increased shear force

In this series only the stress patterns in the implant have been considered The mechanical behaviour of the surrounding bone with its osteoporosis and reduced mechanical strength has not been taken into account and neither has the geometry of the bone-nail interface Further laboratory investigations will therefore be undertaken on cadaveric bone to clarify the mechanical behaviour of the unstable trochanteric fracture without medial support

From this series of experiments it can be concluded that in osteosynthesis of unstable trochanteric fractures a steep placement of the nail plate is to be recommended from purely mechanical considerations.

ACKNOWLEDGEMENTS

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REFERENCES

Cr

Du

Surg 49-A, 440–450

Foster, J C. (1958) Trochanteric fractures of the femur treated by the vitallium McLaughlin nail and plate. *J Bone Jt Surg* 40-B, 684–693

Frankel, V H (1963) Mechanical fixation of unstable fractures about the proximal end of the femur *Bull Hosp Jt Dis (N Y)* 24, 75–84

Foppl, L. & Monch, E. (1972) *Praktische Spannungsoptik*, III Auflage, Springer, Berlin Heidelberg, New York

Grover, H J (1966) Metal fatigue in some orthopedic implants. *J Mater* 1, 413–424

[illegible]

Haboush, E J (1953) Biomechanics of femoral nail and nail-plate insertions in fractures of the neck of the femur *Bull Hosp Jt Dis (N Y)* 14, 125–137

Harvey, J P, Hirsch, C & Wilson, P D (1959) Experimental studies of the stability of internal fixation of the femoral neck fractures in autopsy bones. *Surg Forum* 9, 756–762.

Jensen, J Steen (1978) A photoelastic study of a model of the proximal femur *Acta orthop scand* 49, 54–59

Jensen, J Steen & Michaelsen, M (19 Trochanteric femoral fractures treated McLaughlin osteosynthesis. *Acta orthop* 46, 795–803

Kaufer, H, Matthews, L S. & Sonstegard, D (1974) Stable fixation of fractures. *J Bone Jt Surg* 56-A, 899–90

Martz, C D (1956) Stress tolerance of metal. *J Bone Jt Surg* 38-A, 827–834

Paul, J P. (1967) Forces at the human hip (Thesis) University of Strathclyde, Glasgow

Sarmiento, A (1963) the femur *J Bone Jt Surg* 45-A, 706–722

Spotoft, J (1949) Osteosynthesis of the neck of femur *J Bone Jt Surg* 31-A, 836–846

Correspondence to J Steen Jensen, M D, Tornehøj 23, DK-3520 Farum, Denmark.

ı orthop. scand. 49, 65–67, 1978

RFORATION OF THE URINARY BLADDER AND SMALL TESTINE CAUSED BY A TROCHANTERIC PLATE

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A case is presented of a pertrochanteric plate which penetrated into the pelvis causing perforation of the urinary bladder and small intestine

Key words intestinal perforation, orthopaedic fixation devices, postoperative complications

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trochanteric fractures are common in the erly The frequency of complications after ernal fixation of unstable pertrochanteric ctures is about 25 per cent (Laros & Moore 74) A common complication is penetration the nail through the femoral head into the tabulum and sometimes even into the vis as in the case presented below

SE REPORT

78 year-old female was admitted to our hospital ause of a fresh pertrochanteric fracture of the ıur

Three days after the trauma the fracture was ed with an ASIF 130° blade plate and a lag ew (Figure 1) The postoperative course was eventful The patient returned to the nursing me and was able to walk with support. Two onths after the operation an X-ray examination vealed penetration of the plate through the noral head and acetabulum into the pelvis igure 2) Since the patient was able to walk thout pain reoperation was not considered cessary

Eight months after the operation the patient was ain admitted to hospital because of acute dominal pain X-ray examination showed large lated intestinal loops and several fluid levels. nere was no free gas in the peritoneal cavity The entgenological and clinical findings were typical an ileus (Figure 3) An operation was performed on the same day The ASIF plate was found to have penetrated 5 cm inside the pelvis. Three perforations were seen in the ileum and two perforations in the urinary bladder The plate was removed the ileum resected, and the perforations in the urinary bladder were sutured The patient made a good recovery after the operation

DISCUSSION

Fractures without medial support in the calcar region are considered unstable (Evans 1949, Steen Jensen & Michaelson 1975) with risk of fracture displacement into a varus position (Dimon & Hughston 1967) As a result, the nail used for internal fixation may penetrate through the head into the acetabulum A complication of this type is most likely to occur in elderly patients with severe osteoporosis (Laros & Moore 1974) and in cases of unstable fractures.

The fracture presented above was unstable and the bone was osteoporotic Furthermore the reduction was unsatisfactory and the patient walked without support As a result of this the fracture collapsed and the femoral shaft segment migrated medially and proximally The nail penetrated the hip joint and the pelvis and subsequently perforated



Figure 1 Comminuted pertrochanteric fracture fixed with an ASIF blade plate and a screw.



Figure 2 Two months after the operation blade plate has migrated through the fem and acetabulum into the pelvis

both the urinary bladder and the small intestine

From our experience of the ASIF system, we consider the condylar plate to be preferable to the standard 130° blade plate for fixation of unstable pertrochanteric fractures. The condylar plate gives a better possibility of fixing the fragmented calcar region to support the medial cortex and there is less risk of the nail penetrating into the acetabulum

REFERENCES

Dimon, J H & Hughston, J C. (1967) U intertrochanteric fractures of the hip. *J Surg* 49-A, 440

Evans, E M (1949) The treatment of troc fractures of the femur *J Bone Jt Surg* 440–450

Jensen, J Steen & Michaelson, H Trochanteric femoral fractures treated McLaughlin osteosynthesis. *Acta orthop.* 46, 795–803

Laros, G S. & Moore J F (1974) Complic of fixation in intertrochanteric fractures *Orthop* 101, 110



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A ROENTGEN STEREOPHOTOGRAMMETRIC INVESTIGATION OF INNOMINATE OSTEOTOMY (SALTER)

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The effect of the

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and 24° laterally about a sagittal axis. The acetabulum

The correction as measured with the CE-angle was 25° which the same as the correction about the sagittal axis It is, howev the CE-angle was also dependent upon the rotations longitudinal axes.

Key words hip, osteotomy, pelvis roentgen stereophotogrammetry rhino-phalangeal syndrome

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The principle of innominate osteotomy according to Salter is the redirection of the entire acetabulum in order to increase the joint stability and the contact surfaces between the femoral head and acetabulum (Salter 1961, 1969, Salter & Dubos 1974) The primary indication for this osteotomy is congenital dislocation of the hip with acetabular dysplasia but the method has been used for paralytic hip dislocation, Perthes' disease and certain types of fixed pelvic obliquity (Salter & Dubos 1974) and in acetabular dysplasia with osteoarthritis (Wedge & Salter 1974)

The degree of correction of the acetabulum has generally been estimated by determination of the CE-angle (Wiberg 1939) and has been correlated with the clinical (Crellin 1974, Denton & Ryder 1974, Dubos 1974, Wedge & Salter 1974) in the innominate osteotomy Salter the acetabulum moves about identical with a sagittal axis. The of the acetabulum in the A therefore different pre- and causing difficulties locating the same the determination of the CE-angle To better information about this translation and rotation of the been determined by a roentgen grammetric method (Selvik 1974) tantalum indicators above and below osteotomy level.

ASE REPORT

ie patient was a 17-year-old girl of short stature l with a radiological right-sided acetabular splasia (CE-angle −3°) including deformation of : femoral head and neck with varus position gure 1). Roentgenological investigation showed ieral dysplastic deformations as in the tricho-no-phalangeal (Giedion) syndrome During the :vious 2 years there had been increasing dis-lity in the right hip Clinical examination normal movements in the hip but positive endelenburg's test. As operative procedure an iominate osteotomy on the right side according Salter was chosen.

eration

The operative procedure was performed :ording to the instructions for the operation of 3-dislocated hips with acetabular dysplasia lter 1961 1969 ...



gure 1 AP radiograph of the pelvis showing the splastic right hip

possible to open up the osteotomy enough to place and fix the triangular bone graft. The base was chosen according to Salter (1969) as the distance between the superior and inferior anterior iliac spines and measured about 3 cm The length was estimated to be 5 cm resulting in an angular correction of about 30° with an anteriorly open angle

After 6 weeks in a plaster spica the patient was mobilised. One year after the operation she has no complaints regarding her right hip and she has started to work again Clinically there is now a negative Trendelenburg's test and the range of movement is almost normal. Postoperatively the right side is about 1 cm longer than the left side

Roentgen stereophotogrammetric method

The primary objective of roentgen stereophotogrammetry is to determine the three-dimensional coordinates of structures in the body (Selvik 1974, Olsson 1975, Olsson et al. 1976) Generally, there are no sufficiently distinct points in the body to allow identification with high accuracy in the two projections necessary for a three-dimensional reconstruction Thus, radiopaque indicators, tantalum balls with a diameter of 0 8 mm, were introduced in each skeletal segment studied. Following the technique of Aronson et al. (1974), an indicator was placed in the tip of a needle and deposited during fluoroscopy in the bone into which the needle had been forced 1–2 mm. These tantalum markers serve as measurement points on the radiographs. To allow for a study in terms of three-dimensional rigid-body motion, three indicators were placed in the ilium and three in the segment caudally to the osteotomy

Simultaneous exposures of the pelvis with two roentgen tubes on one film were made pre- and postoperatively On each film, a calibration cage supplied with tantalum indicators, the mutual positions of which are known, was also double-exposed The coordinates of the images of both patient and calibration indicators were then measured by means of an instrument for cartography The information thus obtained was treated by means of a computer so that the three-dimensional positions of the indicators were determined in a laboratory coordinate system. This laboratory coordinate system is defined by the calibration cage markers, which are situated in two planes. The patient is investigated in such a position that the main axes of the body (transverse, longitudinal and sagittal axis) are parallel to those of the cage coordinate system (Olsson et al. 1976). Identical orientation of the patient at different examinations is not necessary

In the subsequent analysis, the rigid-body

motion between the indicated segments was computed and the results were visualized by computer drawings and on radiographs. The iliac indicators were taken as a reference The rotations and translations of the caudal acetabular segment in relation to the ilium were given in the coordinate system of the preoperative investigation In this analysis the reference segment at later investigations is calculated back to its position at the reference examination which explains why identical orientation on different occasions is not needed

Besides the rotation angles about the main axes the total rotation and the position of an axis called the screw axis of the movement were calculated The screw axis is the axis of rotation for a general rigid body displacement which is the closest approximation to the uniquely defined axis of rotation in a pure rotatory movement Using the screw axis description the rigid body motion is a rotation about and a translation along the same axis The position of the screw axis was related to frontal lateral and axial orthographic projections of the indicators drawn by computer To visualize it better it also was drawn on frontal and lateral radiographs exposed with the central ray passing through the midpoint of the indicators in the caudal segment The position of the axis was related to this midpoint but no correction [illegible] made for the radiograph being a central projection

In contrast to the rotation angles, the translation varies over a segment if the motion is not a pure translation As illustration the translation [illegible] given for a point in the roof of the acetabulum where one of the indicators was placed (Figures [illegible] and 3)

The precision of the method was earlier estimated to be approximately 0 2° for the rotations [illegible] and 0 1 mm for the translations along the [illegible] coordinate axes (Olsson 1975) In the [illegible] two roentgen films were exposed [illegible] postoperative investigations Comparing rotation angles and translations obtained [illegible]

positions differed 0 1 mm





Figure 2 Right hip postoperat[illegible] and the screw axis are m[illegible] indicator further marked with[illegible] radiograph centred on the [illegible] *view of the pelvis [illegible] a [illegible] a horizontal central [illegible] lar segment. The [illegible] [illegible] as in Figure 2*

ESULTS

he acetabulum rotated 22 3° forwards out a transverse axis (the cranial part moved rwards), 9 3° laterally about a longitudinal is (the ventral part moved towards the right le of the patient) and 23 6° laterally about a gittal axis (the cranial part moved towards e right) in relation to the right ilium These can also be expressed as a total tation of 32.4° about the screw axis igures 2 and 3) It is found that this axis sses from the right, dorsal and cranial part the pelvis to the left, ventral and caudal rt, and it is noted that it passes cranially to osteotomy and cranially to the pubic mphysis.

The indicator in the acetabulum (Figures 2 3) was translated 1 6 mm towards the side of the patient along a transverse s, 20 5 mm caudally along a longitudinal is and 18 9 mm dorsally along a sagittal axis relation to the right ilium The translation ng the screw axis was 4 8 mm in the ward direction

SCUSSION

e motion of the segment caudally to the teotomy, including the acetabulum, was culated in relation to the segment cranially the osteotomy, but it was not known which segments was moving or if they both ved in opposite directions If only the etabulum had moved and the rest of the lvis had constituted a rigid body the etabulum should have rotated about an axis nich passed through the pubic symphysis. As is was not the case (Figure 2) it is concluded at some motion also took place in one or th of the sacroiliac joints. This is indirect idence that not only did the acetabulum ove downwards, but that the ilium also oved upwards This fact must be kept in nd when the operation is planned so it can compensated for

Concerning the size of the triangular bone aft, Salter (1969) has found that the length of the base is no problem as the distance between the superior and inferior anterior iliac spines increases with age and compensates for the increased demand in size. However as small children have relatively greater joint instability it can be anticipated that the ilium probably also moves relatively more in relation to the transverse plane in younger than in older children Thus the gained tilt of the acetabulum will be relatively less in younger children

In this case the CE-angle was changed from −3° to 22° by the osteotomy, indicating a better covering by the acetabulum which has also been found in previous investigations (Crellin 1974, Denton & Ryder 1974, Salter & Dubos 1974, Wedge & Salter 1974) As mentioned above, the calculation of the CE-angle is difficult However, the noted change is about 25°, which is the same as the rotation about the sagittal axis (24°) There is also a considerable rotation about the transverse axis (22°), which contributes to a better covering of the femoral head The rotation of 9° laterally about the longitudinal axis will therefore, in this particular case, not affect the height of the acetabular edge seen in the AP-projection

REFERENCES

[illegible] (1974) [illegible] congenital dislocation and subluxation of the hip. *Clin. Orthop* 98, 171–177

Denton, J R. & Ryder, C. T (1974) Radiographic follow-up of Salter innominate osteotomy for congenital dysplasia of the hip *Clin. Orthop* 98, 210–213

Olsson, T H (1975) A roentgen stereophotogrammetric study of the kinematics of the spine Thesis, Lund.

Olsson, T H Selvik, G & Willner, S (1976). Kinematic analysis of spinal fusions. *Invest. Radiol.* 11, 202–209

Salter, R. B (1961) Innominate osteotomy in the treatment of congenital dislocation and subluxation of the hip *J Bone Jt Surg* 43 B 518–539

Salter, R. B (1969) An operative treatment for congenital dislocation and subluxation of the hip in the older child *Recent advances in orthopaedics*, Ed Apley, A G, pp 325–360 Churchill, London

Salter, R B & Dubos, J-P (1974) The first fifteen years' personal experience with innominate osteotomy in the treatment of congenital dislocation and subluxation of the hip *Clin Orthop* 98, 72–103

Selvik, G (1974) A roentgen sterophotogrammetric method for the study of the kinematics of the skeletal system. Thesis, Lu

Tachdjian M D (1972) *Pediatric orthop* Saunders Philadelphia, London, Toronto

Wedge, J H & Salter, R B (1974) osteotomy Its role in the arrest of degenerative arthritis of the hip in the *Clin Orthop* 98, 214–224

Wiberg G (1939) Studies on dysplastic and congenital subluxation of the hip joint *chir scand* 83, Suppl. 58

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UADRICEPS FUNCTION FOLLOWING INDIRECT NAILING F FEMORAL SHAFT FRACTURES

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rgery O and Ø, Odense, Denmark

A series of 24 adult patients with isolated, unilateral fractures of the femoral shaft treated by indirect Street Hansen nailing is submitted Follow up included clinical and radiological assessment as well as measurement of [illegible]

[illegible]

nailing

Key words quadriceps, function tests, strength fracture of femoral shaft, sequelae

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· most important requirements in modern tment of fractures are the achievement of on as well as normal physical and social ction in the shortest possible span of time with the least possible risk to the ividual patient (Charnley 1963). But as this olves several factors, the question of ority arises – and thus variations in the ice of treatment as well as in the assess-nt of the therapeutic results.

n the Odense University Hospital the tine treatment of fractures of the femoral ft has been for several years traction in ldren and intramedullary nailing by a ssive, rhombic Street-Hansen nail in adults. to 1969 the operation involved open uction with retrograde introduction of the l. Since that time the routine surgical cedure has been closed reduction, roducing the intramedullary nail from the ater trochanter to the femoral condyle der transillumination As an additional parameter in the assessment of the therapeutic results, we have introduced measurement of the strength of the thigh muscles.

In 1972 the present authors submitted the therapeutic results of fractures of the femoral shaft in adults and in 1974 those in children, with special attention to muscle function (Damholt & Zdravkovic 1972, Damholt & Zdravkovic 1974)

PATIENTS

In this paper we are submitting the results of treatment of unilateral fractures of the femoral shaft in adults, having no other injuries, by closed reduction and indirect nailing by the Street-Hansen method.

The material comprises 24 patients, 6 females and 18 males in the age range 16–66 years, mean age 25 years. The follow-up period ranged from 2–6 years, mean 2.7 years.

Table 1 gives the situation in which the accidents occurred. The majority of patients had

Salter, R B (1969) An operative treatment for congenital dislocation and subluxation of the hip in the older child *Recent advances in orthopaedics*, Ed Apley, A G, pp 325–360 Churchill, London

Salter, R B & Dubos, J P (1974) The first fifteen years' personal experience with innominate osteotomy in the treatment of congenital dislocation and subluxation of the hip *Clin Orthop* 98, 72–103

Selvik, G (1974) A roentgen sterophotogrammetric method for the study of kinematics of the skeletal system. Thesis, Lu

Tachdjian M D (1972) *Pediatric orthop* Saunders Philadelphia, London, Toronto

Wedge, J H & Salter, R. B (1974) Innomi osteotomy Its role in the arrest of seco degenerative arthritis of the hip in the *Clin Orthop* 98, 214–224

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Table 3 Results of measurement of strength

	%	Isometric strength No of patients	Dynamic endurance No of patients
A>U	⩾ 20 1	1	1
	20 0–10 1	1	1
	10 0– 0 1	4	2
A=U	0	4	3
A<U	0 1–10 0	4	7
	10 1–20 0	4	3
	⩾ 20 1	6	5

A=affected leg, U – unaffected leg
The measurements of strength were calculated according to the formula U–A in per cent of U
Calculation formula of isometric strength and dynamic endurance worked out in collaboration with Sv Molbech, M.Sc., of the Polio Institute Hellerup/Copenhagen (1971) (Formula obtainable on request from the authors.)

Table 4 Results of strength and endurance measurements in patients under and over 25 years of age Figures in brackets indicate number of patients

	Percentage decrease of strength in affected leg	
	Isometric	Dynamic
Patients under 25 years (18)	6 5	7 5
Patients over 25 years (6)	22 8	33 3

ference showed no difference or a ıce of less than 2 cm

results of measuring strength were ıred with the measurements of ference For isometric strength the tion coefficient was r=0 39 and for ic endurance r=0 49 Thus, the cor- ding determination coefficients r^2 were nd 0 24, respectively In other words, a on in one parameter can explain only 15 nt and 24 per cent, respectively, of the on in the other

follow-up 22 of the 24 patients were yed in the same or heavier work than the accident Two patients were not yed one was out of work and one was ing school

Prior to the accident 10 of the patients had been involved in competitive sport Of them 6 went back to the same sport Comparison of patients involved in sport and those who were not showed no statistically significant difference in the results of strength measurements.

Table 4 gives the mean decrease in isometric strength and dynamic endurance in the affected leg in per cent of the unaffected one – for patients under and over 25 years of age There is a clear tendency towards a more marked decrease of strength in the older patients, but owing to the small number involved the difference is not statistically significant at the 5 per cent level. Two patients with rotation deformity showed a decrease of 24 per cent and 43 per cent in the affected leg

Table 5 Comparison of statistical calculations in which the measurements of strength and endurance in the affected leg are related to the unaffected leg

	I	II	III
No of patients	53	33	24
Isometric strength	$t=6\ 42$ $P<0\ 001$	$t=3\ 18$ $P<0\ 01$	$t=2.1$ $P<0\ 05$
Mean decrease	30 6%	12 9%	10 5%
Dynamic endurance	$t-5\ 4$ $P<0\ 001$	$t=4\ 43$ $P<0\ 001$	$t=1\ 99$ $P<0\ 05$
Mean decrease	33 0%	19 5%	12 2%

Group I Fractures treated by direct nailing
Group II Conservatively treated fractures in children.
Group III Fractures treated by indirect nailing
t = Student's test.

in isometric strength and dynamic endurance, respectively The patient having a 4 cm shortening also had a decrease of strength, of 30 per cent and 75 per cent, respectively

DISCUSSION

As parameters in evaluating the results of treatment of fractures of the femoral shaft we have introduced measurements of muscle strength and endurance The present study is a continuation of our investigations into quadriceps strength in patients treated for fractures of the femoral shaft.

The 1972 series included 53 adults treated by open reduction and direct intramedullary nailing by the method of Street-Hansen (Group I) The series from 1974 comprised 33 children treated by traction (Group II) Danckwardt-Lillieström & Sjögren, in 1976, used the same principle for measuring strength and endurance in a series of 23 patients, but only 17 of them had been treated by intramedullary nailing alone *In the present study* we followed 24 patients with fractures of the femoral shaft without other injuries (Group III).

Table 5 lists the results of isometric strength and dynamic endurance measurement of knee extension in patients with fractures of the femoral shaft – treated by the three methods mentioned above

The decrease of dynamic endura[illegible] greater than that of isometric strength [illegible] cases. The ratio between these two [illegible] ments was approximately the same in [illegible] series. On the other hand, the decr[illegible] *isometric strength as well as in* [illegible] endurance in the affected leg was cons[illegible] greater in group I patients, treated by [illegible] *reduction (mean about 30 per cent)* [illegible] group III patients, treated by closed re[illegible] and indirect intramedullary nailing [illegible] about 12 per cent) The results for [illegible] (group II) treated by traction are inter[illegible] between those for groups I and *III*, [illegible] to the latter

Conclusion

In group I *from* 1972, treated by [illegible] nailing, the mean decrease in streng[illegible] about 30 per cent, which is [illegible] abnormal. In the present *material* trea[illegible] indirect nailing the mean decrease was [illegible] about 10 per cent, and in patients [illegible] years of age it was considerably less [illegible] difference is within the range of norm[illegible] symmetrical muscle groups (Hecbe[illegible] 1964) In other words, the indirect meth[illegible] intramedullary nailing has shown [illegible] advantages over the direct, open method [illegible] former, moreover, obviates further tra[illegible] *tion of the muscles* and reduces the r[illegible] secondary infection at the *fracture* [illegible]

-EFERENCES

ley, J (1963) *The closed treatment of common ctures*, 3 ed., Livingstone, Edinburgh.
olt, V & Zdravkovic, D (1972) Quadriceps iction following fractures of the femoral shaft. *ta orthop scand* 43, 148–156
iolt, V & Zdravkovic, D (1974) Quadriceps iction following fractures of the femoral shaft children. *Acta orthop scand* 45, 756–763
wardt Lilliestrõm G & Sjögren S (1976) Postoperative restoration of muscle strength after intramedullary nailing of fractures of the femoral shaft. *Acta orthop scand* 47, 101–117
Dencker, D M. (1963) *Fractures of the shaft of the femur* Orstadius Boktryckeri Aktiebolag Goteborg
Heebøll Nielsen, K. R (1964) Muscular asymmetry in normal young men. Commun. Test Obs. Dan Nat Ass. Inf Paral. No 18

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HIGH TIBIAL OSTEOTOMY FOR RHEUMATOID ARTHRITIS OF THE KNEE

A One to Six Year Follow-Up Study

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Although high tibial osteotomy for osteoarthrosis of the knee joint [illegible] *recognized, its place in the management of rheumatoid arthritis of* [illegible] much less well established Thirty-six rheumatoid knees were reviewed [illegible] years following tibial osteotomy The results were 42 per cent good [illegible] cent satisfactory and 39 per cent poor No patient remained free of [illegible] more than 3 years, and recurrence of pain was not always associ[illegible] recurrence of deformity Varus knees did considerably better than [illegible] knees despite some technical errors. Maintenance of a normal femo[illegible] angle range of 164° to 177° at follow up was important but not as [illegible] osteoarthrosis of the knee The beneficial effect of tibial oste[illegible] rheumatoid arthritis of the knee seldom lasted more than 3 years after [illegible] time an increasing number of bad results were seen It was conclu[illegible] high tibial osteotomy was a satisfactory procedure for rheumatoid art[illegible] the knee but its efficacy was not comparable to that seen in osteoar[illegible] nor was its effect long-lasting

Key words rheumatoid arthritis, knee, tibial osteotomy

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High tibial osteotomy for osteoarthrosis of the knee is now a well recognized procedure (Wardle 1962, Coventry 1965, 1973, Bauer et al 1969, Jackson et al 1969, Jackson & Waugh 1974, Harding 1975) It is also known that good results can last up to 10 years (Seal & Chan 1975) The efficacy of tibial osteotomy in the management of rheumatoid arthritis of the knee, however, has not been well established The purpose of this report is to assess the value of tibial osteotomy in rheumatoid arthritis of the knee and to evaluate the importance of maintaining the correction within Bauer's femoro-tibial angle range of 164°–177° (Bauer et al 1969) The femoro-tibial angle is defined as the lateral angle formed between the axes of the femur and tibia in the longitudinal plane during [illegible] bearing

PATIENTS AND METHODS

From June 1969 to August 1974 35 p[illegible] underwent high tibial osteotomy for rh[illegible] arthritis of the knee in Bath. Two pa[illegible] bilateral osteotomies of which one proce[illegible] outside the period of study Thirty-six oste[illegible] are thus available for assessment. No pa[illegible] lost to follow-up and all were seen and ex[illegible] one of the authors (JPP). The indica[illegible] osteotomy were pain, deformity and instab[illegible] length of follow up is from 1 to 6 years [illegible] average of 3 years.

·operative profile

There were 28 females and 7 males with an age .n of 22 to 78 years, the average age being 61 rs. Twenty-four patients were seropositive at time of surgery and the same number of ients were on steroid medication The duration heumatoid arthritis at operation was from 5 to years. With the exception of five patients all had ltiple joint involvement, often affecting the hips l feet. Preoperatively four patients used crutches l one was confined to a wheelchair Thirteen ents had undergone surgery to the affected knee nonths to 3 years prior to osteotomy The gical procedures included twelve synovectomies, e being associated with patellectomies and one t's femoral condylar replacement.

rative details

here were 29 valgus knees and seven varus s. The deformities as measured by Bauer's oro-tibial angle on weight-bearing ranged from ° to 193° With one exception, closing wedge sion was the method used for correction of the rmity Two osteotomies were carried out w the tibial tubercle since the deformities were idered too great for correction above the rcle Two patients had synovectomy at the

ntained for a period of 6 to 8 weeks.

mmediate postoperative radiographs showed all knees were corrected to a femoro-tibial e range of 165° to 180°, thus being without ption within the femoro-tibial angle range for nal knees. At review the range had widened to ° to 190°

plications

here was

joints.

hod of assessment

t review standard radiographs of the knees e taken together with weight bearing views. ier's femoro tibial angle was measured eumatoid activity was assessed both clinically by estimation of the rheumatoid factor and imentation rate Examination of the knee uded measurement of range of movement, essment of collateral stability and synovial ivity Analgesics intake was noted In umatoid arthritis multiple joint involvement often makes specific assessment of individual joints difficult and at the same time probably not very meaningful Pain relief, however, can be assessed. Thus Coventry (1973) in his evaluation of rheumatoid knees graded results according to pain relief only We have graded our results as good satisfactory and poor according to the following criteria

Pain
- Grade 1 No pain in knee
- Grade 2 Occasional analgesics for knee pain
- Grade 3 No change/worse

Mobility
- Grade 1 Improved
- Grade 2 No change
- Grade 3 Decreased

Function
- Grade 1 Considerable improvement
- Grade 2 Improved
- Grade 3 No change/worse

GOOD	All grade 1, one grade 2, no grade 3
SATISFACTORY	One grade 1, all grade 2, no more than one grade 3
POOR	No grade 1, two or more grade 3

RESULTS

Of the 36 knees assessed 15 knees were classified as good (42 per cent), 7 as satisfactory (19 per cent) and 14 as poor (39 per cent)

Pain relief

At review eight patients did not complain of pain in their knees. It is important to note that none of these eight patients had had the osteotomy for more than 3 years. Nine patients stated that their knees were much less painful than before surgery and they only took occasional analgesics for knee pain Four replied outright that surgery had been totally unsuccessful as regards pain relief Another eight patients had already undergone further surgery to their knees with pain as the main reason for revision surgery

The efficacy of tibial osteotomy for pain relief in rheumatoid knees is thus poor and

contrasts sharply with the results in osteoarthrosis Our findings in this series are not specifically related to the general level of rheumatoid activity among patients since there was an equal distribution of patients with positive RA Latex and raised sedimentation rate at the time of surgery and at the time of review

The most important finding as regards pain relief is that in no knee did pain relief last for more than 3 years Indeed with passage of time increase in pain is more than likely

Range of movement

Comparing the range of movement measured at follow up with that recorded preoperatively, 24 knees (66 per cent) had an unchanged range of movement Five knees had an increased range, the maximum being 50°, all five knees were graded good Seven knees had a diminished range, the maximum being 70° Of these five were graded poor and two satisfactory, one of the latter knees became ankylosed following surgery with concomitant decrease in pain.

Fifteen knees had a fixed flexion contracture at follow up with a range of 5 to 30° (average 11°) There seems to be no definite correlation with results except when the deformity is severe There was one case of recurvatum of 10° at review giving a poor result

Functional assessment

In contrast to osteoarthrosis where functional improvement is excellent following high tibial osteotomy, only 10 out of 35 patients (36 knees) admitted to definite improvement following surgery Patients' acceptance of a second and similar procedure is a good index of subjective assessment and in this series only two patients had subsequent osteotomy of the contralateral knee. In one series of osteoarthrosic knees (Seal & Chan 1975) 11 out of 47 patients had bilateral osteotomies. Another indication of relative lack of functional improvement is that four patients required crutches and three were confined to wheelchairs at review u to four and one, respectively, before

Femoro-tibial angle at follow-up

Immediate postoperative rad showed that all knees were correc femoro-tibial angle range of 165°–1 without exception within the fem angle range for normal knees. At r range had widened to 155°–190°

The femoro-tibial angle at foll shown in Figure 1, preoperatively va being indicated by brackets.

Preoperatively valgus knees There portionately equal distribution an good, satisfactory and poor groups with a normal femoro-tibial angle at f This is in distinct contrast with knees where maintenance of a normal tibial angle is vitally important for result In one series, all poor results f the normal femoro-tibial angle rang Chan 1975)

Preoperatively varus knees There seven varus knees in this series but interest to note that firstly, a

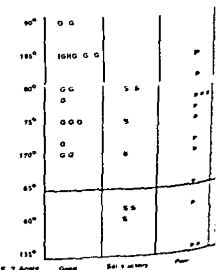


Figure 1 Femoro-tibial angle at follow-up (G)(S)(P) = Knees in varus preoperatively G S P = Knees in valgus preoperatively

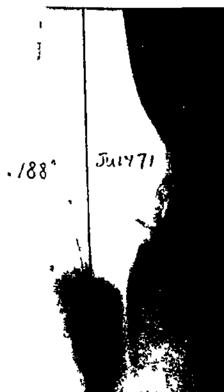
nber belonged to the good group (five out of en) and secondly, despite undercorrection results remained good (Figure 2) The nbers are too small for definite statement the results suggest that varus knees do ter than valgus knees. This finding applies n to knees with severe articular damage at time of operation (Figure 2) The same iervation has also been made in coarthrosic knees (Harding 1975)

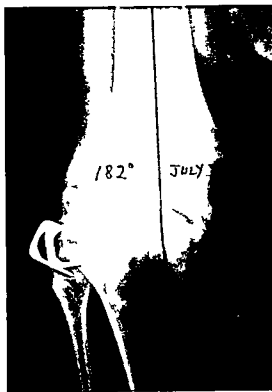
or results

Fourteen knees were assessed as poor at iew (39 per cent) Of these eight had dergone further surgery at 1 to 6 years owing tibial osteotomy The reasons for ision surgery were recurrence of pain in all ients deformity in four and instability in patient

Some failures were technical in nature There was one case each of the osteotomy being carried into the joint, a staple protruding into the joint and over-correction. Five knees were under-corrected even though the imme diate postoperative radiographs showed correc tion to be within Bauer's femoro-tibial angle This was due to the fact that collateral laxity was not recognized at operation resulting in apparent rather than real correction of the deformity (Figure 3) Previous surgery to the knee prejudices the results, seven out of thirteen of these knees were graded poor at review (55 per cent) The reason for this is not clear since analysis of clinical details and radiographs showed that this group did not contain an undue number of radiologically severely affected knees which might have accounted for the high percentage of failure

Three knees showed radiologically mild rheumatoid arthritis at the time of surgery but subsequently deteriorated rapidly with an





gure 2 Varus knee Preoperative femoro-tibial angle 188° July 1971 Follow-up angle 182° July 75 Note under-correction Result good

eventual poor result The knees however remained well corrected at the time of review

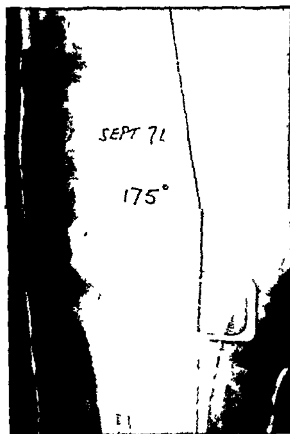
Up to 3 years postoperation there is a bias towards a good result, after which time a progressive worsening of results is seen usually associated with recurrence of pain and less frequently with recurrence of deformity (Table 1)

Good results

Fifteen knees were graded as good (42 per cent) Five of these were preoperatively varus knees and measurement of femoro-tibial angle at review showed that they were still in varus. Of the ten preoperatively valgus knees graded as good at review, one had been over corrected and the rest had been maintained within a normal femoro-tibial angle range Three knees in the good group were clinically and radiologically severely affected at the time of operation but subsequently did well. Th no obvious explanation for this except th knees were either well corrected and correction was subsequently maintai that the knees were in varus at time of s Sloping joint line was not significant p the femoro-tibial angle was within limits.

DISCUSSION

Corrective high tibial osteotomy has gained an important place in the manag of osteoarthrosis of the knee and good re 70 per cent or more can be expected maintained for many years after (Coventry 1973, Seal & Chan 1975). The also general agreement on the importa correction of the deformity to a range Bauer's femoro-tibial angle (Bauer et al 1



DEC 71

163°

Figure 3 September 1971 Postoperative angle 175° Note correction is apparent rather than real & lateral collateral laxity December 1971 Femoro-tibial angle out of plaster cast 163° Result poor

ırris & Kostuik 1970) Information on the lue of tibial osteotomy for rheumatoid knees wever is scarce Of the 474 knees evaluated Coventry (1973), Jackson & Waugh (1974) d Harding (1975), 37 were rheumatoid knees. ıs present study while small is therefore one the largest series confined specifically to eumatoid knees. It is clear from this study at the results of osteotomy in rheumatoid ıees differ from those obtained in os-oarthrosic knees as follows

Pain relief is of much shorter duration There is no knee in this series with pain relief lasting more than 3 years. In osteoarthrosic knees, recurrence of pain is usually associated with recurrence of deformity and this is not necessarily so in rheumatoid knees.

Functional improvement is by no means as dramatic as that obtained in osteoarthritic knees, nor is the duration of improvement maintained for as long a period of time This is true both subjectively and objectively It is important to point out, however, that in rheumatoid arthritis any gain in function, albeit minor, is a real asset to an already crippled patient and any relief in pain, even of limited duration is advantageous in reducing disability

Maintenance of the femoro-tibial angle, though important, is not as vitally significant as in osteoarthrosis of the knee The reason for this is probably multifactorial since rheumatoid arthritis is a generalized disorder and there are more problems involved than simple mechanical correction of varus or valgus deformity Varus knees treated by osteotomy require further analysis, since if our results are reproducible in a larger series then high tibial osteotomy for this deformity can lead to the same success rate as in osteoarthrosic knees.

It is vital to be meticulous with operative details. As bone in rheumatoid patients is usually osteoporotic, osteotomy is technically easy but may readily produce tibial plateau fracture or penetration of the joint Furthermore, staple fixation can be difficult to achieve and may result in their insertion through the subchondral bone into the joint in error

5 Steroid medication in this series had [illegible] significant effect on results at review [illegible] problems were observed as regards wound healing, bone union and infection associated with steroid intake There was one case of infection in 36 knees.

6 Mild and burnt out rheumatoid and varus knees appear to do best following high tibial osteotomy Advanced disease should be avoided A sloping joint-line is not a contra-indication, provided good alignment is obtained at operation One should aim to over correct rather than under correct, as in osteoarthrosic knees. Due allowance for collateral instability is necessary and can only be checked and avoided by radiography at operation A few knees moderately diseased at operation, subsequently deteriorated rapidly, both clinically and radiologically At present no means of predicting these changes is known, a solution to this problem would greatly improve results

7 The following categories tend to give poor results, viz , knees with severe fixed flexion deformity, with marked collateral instability, and those subjected to previous surgical procedures. Valgus knees tend to do less well than varus knees. Valgus, if under corrected, disposes to failure Radiologically advanced rheumatoid joints will probably not respond.

8 Approximately 60 per cent good and satisfactory results were obtained in this

Table 1 Influence of time elapsed since operation on results

Length of time since operation	Good	Satisfactory	Poor
Up to 3 years	11	4	4
More than 3 years	4	3	10

series, with a follow-up of 1 to 6 years. However, as is shown in Table 1, the number of long-term good and satisfactory results beyond 3 years are considerably reduced If the results of tibial osteotomy are to be compared with other procedures such as double osteotomy (Benjamin 1969) and total joint replacement, the follow-up period must be at least 3 years since prior assessment will give a disproportionate number of good results

REFERENCES

Bauer, G C H, Insall, J & Koshino, T (1969) Tibial osteotomy in gonarthrosis (osteoarthritis of the knee) *J Bone Jt Surg* 51-A, 1545–1563

Benjamin, A (1969) Double osteotomy for the painful knee in rheumatoid arthritis and osteoarthritis. *J Bone Jt Surg* 51-B, 694–699

Coventry, M B (1965) Osteotomy of th

Bone Jt Surg 55-A, 23–48

Harding, M L (1975) Tibial osteot arthritis of the knee *J Bone Jt Sur* 110

Harris, R W & Kostuik, J P (1970) Hi osteotomy for osteoarthritis of the knee. *Jt Surg* 52-A, 330–336

Jackson, J P, Waugh, W & Green, J P

Jac

Se

osteotomy for osteoarthrosis of the knee to ten year follow-up study *Acta orthop* 46, 141–151

Wardle, E N (1962) Osteotomy of the t fibula *Surg Gynec Obstet* 115, 61-64

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rthop scand. 49, 85–88, 1978

E SAAB JIG: AN AID IN HIGH TIBIAL OSTEOTOMY

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To increase the precision of high tibial osteotomy a surgical tool has been developed. The instrument is described The precision obtainable using the instrument is found to be significantly ($P < 0.001$) higher than that obtained when operating without the instrument

Key words gonarthrosis, high tibial osteotomy, surgical tool

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h tibial osteotomy is commonly used in the tment of moderately severe gonarthrosis ı varus or valgus deviation. The size of the ge to be removed to correct the deviation letermined in various ways in different ıcs (Devas 1969, Coventry 1973, Maquet 6, Edholm et al 1976 and 1977, Myrnerts Vennberg 1977) Freedom from pain is five es more likely in well-corrected patients ı in patients who have been either over- or ercorrected (Hagstedt 1974) A necessary dition for a good correction is that the lge removed is exactly of the size ermined preoperatively To increase the sibility of removing exactly the pre-ermined size of wedge at high tibial eotomy, a surgical tool has been developed the Department of Orthopaedic Surgery, ikoping, Sweden, in co-operation with AB-Scania The instrument has been called SAAB jig Its construction and function ı be seen in Figures 1–7 The precision of : instrument has been examined in nection with a clinical study of narthrosis.

METHOD

The size of the wedge that was actually removed at operation was determined by measuring the angle between the long axis of the tibia and a tangent to the articulating surfaces of the tibial condyles on frontal x-rays of the knee, taken before and immediately after the operation The actual size of the wedge removed was compared with that intended. The intended wedge size was determined by three-point-measurement (Edholm et al 1976 and 1977, Myrnerts & Wennberg 1977) The difference between the intended wedge size and the size of the wedge actually removed has been used as a measure of the precision of the surgical method.

MATERIAL

The difference between intended wedge size and actual wedge size was determined in 56 patients operated on using the SAAB jig (group A) and in 40 patients operated on without the jig (group B) In the latter operations, prefabricated models of the wedge or the method in which 1 mm on the cortical surface corresponds to 1° of wedge were used as an aid in determining the wedge size to be removed

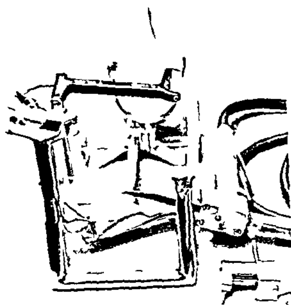


Figure 1 The jig consists of a metal frame for three-point suspension of the lower leg An articulated arm, that directs a saw in a well defined plane, is mounted on this frame



Figure 3 With this mechanism the [illegible] position of the wedge can be determined [illegible] articulated saw arm in positions [illegible] respectively (see arrows) a wedge is [illegible] size of which can be read on the [illegible] mechanism



Figure 2 The leg is suspended by two metal points that are drilled into the bone laterally and medially at the knee and by a circular holder that can be tightened around the ankle



Figure 4 The osteotomy is carried out

RESULTS

The results of a comparison between [illegible] surgical methods are shown in Table 1 [illegible] been possible to reduce the percentage [illegible] corrections (difference > /6/°) from 22.[illegible] A statistical comparison of the mean differences between the intended and [illegible] wedge size in the two groups [illegible] significant improvement in favour of the jig ($P < 0.001$). The SAAB jig is easy to [illegible] injuries to vessels or nerves have been [illegible]



re 5 After the wedge has been removed and the es of the osteotomy have been approximated aw is changed for a special drill and two holes bored parallel to the line of the osteotomy



Figure 6 The osteotomy is stabilized with one or two staples

Figure 7 Postoperative x rays

Table 1 The difference between intended wedge size and actual wedge size measured immediately postoperatively

Group/Diff	/0°–2°/	/2°–4°/	/4°–6°/	>/6°/
A	55 3%	26 8%	12 5%	5 4%
B	30 0%	22 5%	25 0%	22 5%

DISCUSSION

It is still not known with any certainty what is the optimal degree of correction in high tibial osteotomy In addition, the correction can either increase or decrease while the osteotomy is healing Nevertheless, it seems that one prerequisite for a good correction is that the size of the wedge removed at operation is as close as possible to the predetermined size and we have found the SAAB jig to be of decided value in achieving this

REFERENCES

Devas, M (1969) High tibial osteot arthritis of the knee *J Bone Jt Su* 95–99

Edholm, P, Lindahl, O, Lindholm, B., R, Olsson, K-E & Wennberg E (19 instability *Acta orthop scand.* 47, 655-

Edholm, P, Lindahl, O, Lindholm, B., R, Olsson, K-E & Wennberg E (19 instability and tibial osteotomy *Acta scand* 48, 95–98

Hagstedt, B (1974) High tibial osteot

examination technique in gon *International Orthopaedics (SICOT)* 1

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ιΕOCHONDRITIS DISSECANS OF THE TALUS

ENS SCHARLING

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Nineteen patients showing radiological subchondral changes in the trochlea tali are submitted. In 16 cases the changes were osteochondritis dissecans, either with sequestra or with multilocular cysts, and in three cases so-called synovial cysts. The site was in 13 cases the upper medial and in five cases the upper lateral angle of the talus, and in one patient both In five of the six lateral cases symptoms had started following trauma while this applied to only five of the 13 medial cases. The three solitary cysts showed marked similarity to the other cases with respect to symptoms, signs, operative findings, as well as possible traumatic aetiology

Key words osteochondritis dissecans, trochlea tali

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ochondritis of the Talus

uring the period 1970–1976 a total of 19 ents showing radiological changes sub-drally in the trochlea tali were treated in Department of Orthopaedic Surgery, tral Hospital, Næstved According to the rature osteochondritis dissecans is ommon at this site However, the fairly e number of patients presenting during 7-year period appears to indicate that the ase is more common than previously umed.

n some cases the changes represented ochondritis dissecans, in others solitary chondral cysts In the literature these two ditions are discussed separately, but in the sent series there were so many items of ilarity that it may be asked whether they in fact two different manifestations of the ne disease

TIENTS AND METHODS

19 patients had definite radiological changes bchondrally in the talus. In addition, there was a case that showed, at operation, a detached flake of cartilage from the articular surface of the talus and two in which the cartilage was merely soft and a bit discoloured in one area, however, no radiological [illegible] seven left-sided The mean age at diagnosis was 36 years, range 15–63 years The mean age of the males was 13 years younger than that of the females of whom only two were under 50, whereas no man was over 50

All the patients had pain provoked by weight-bearing in several cases only intermittently, and five patients also suffered occasionally from rest pain In four cases there were episodes of locking in the ankle joint, and another four patients had a sensation of sometimes "missing" a step Clinical signs were modest, in eight patients absent In four cases there was tenderness anteriorly or posteriorly to the malleolus in which the changes were localized Six patients felt tenderness on forced movements of the ankle joint, and in five there was slight limitation of motion The mean duration of symptoms was rather more than 2 years

An adequate *trauma* was reported by nine patients Eight of them had sustained fairly severe distortion traumas and suffered from persisting pain until diagnosis, from 2 months to 3 years later In four cases an X-ray examination had been done primarily after the *distortion* but no changes had

Table 1 The difference between intended wedge size and actual wedge size measured immediately postoperatively

Group/Diff	/0°–2°/	/2°–4°/	/4°–6°/	>/6°/
A	55 3%	26 8%	12 5%	5 4%
B	30 0%	22.5%	25 0%	22.5%

DISCUSSION

It is still not known with any certainty what is the optimal degree of correction in high tibial osteotomy In addition, the correction can either increase or decrease while the osteotomy is healing Nevertheless, it seems that one prerequisite for a good correction is that the size of the wedge removed at operation is as close as possible to the predetermined size and we have found the SAAB jig to be of decided value in achieving this.

REFERENCES

Coventry, M (1973) Osteotomy about the knee for degenerative and rheumatoid arthritis *J Bone Jt Surg* 55-A, 23–48

Devas, M (1969) High tibial oste arthritis of the knee *J Bone Jt S* 95–99

Edholm, P, Lindahl, O, Lindholm, B. R, Olsson, K-E & Wennberg E (instability *Acta orthop scand* 47, 6

Edholm, P, Lindahl, O, Lindholm, B. R, Olsson, K-E & Wennberg E (instability and tibial osteotomy *A scand* 48, 95–98

Hagstedt, B (1974) High tibial os [illegible]

examination technique in go *International Orthopaedics (SICOT*

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ıre 3 Unılocular cyst ın the upper medıal angle e talus

s the only finding was frayed and soft cartılage, three cases the cartılage was definitely rmined, and ın seven cases ıt was more or less ched The approach to the joınt was most often chiselling off the medial malleolus *after first* ng made a burr canal up through the malleolus r the operatıon, the malleolus was fixed with a or screw In cases where the disease was lized laterally, the approach was anterior or erior to the lateral malleolus In all cases ing was done *into* the site of osteochondritis or ugh the cysts, except ın one case ın which a was filled with bone chips. Moreover loose ilage was removed ın six cases Postoperatively patients wore a walking cast for 4–6 weeks.

RESULTS

Of the 19 patıents one has died and one has undergone talocrural fusion Below, this case will be excluded because of very severe preoperative osteoarthritis. In two cases the follow-up period was less than 6 months In the remaining 15 it ranged from 7 months to more than 5 years, mean 33 months

Eight of the 15 patients were free of pain, five had mild pain, and in two the pain was unchanged In all cases the pain occurred only after prolonged weight-bearing, and especially when walking on rough ground Only two had such severe complaints that occasionally they had to stay away from work In all seven patients with pain this complaint restricted their spare time activities. Table 2 lists the results at follow-up, as regards pain related to the sites of the X-ray changes in the talus and to a possible history of trauma Only cases having a follow-up period exceeding 6 months are included None of the patients had subsequently received treatment

Limitation of motion in the ankle joint was found in seven patients, equally distributed among those with and without pain The limitation never exceeded 15° and most often affected dorsiflexion or plantar flexion, rarely pronation or supination A couple of the patients were unable to squat properly

Alterations in the *radiological* appearances from the preoperative films to exposures at follow-up were classified, in 13 of the 15 cases, into changes deep in the talus, changes on its surface, and osteoarthritic changes in the ankle joint In five cases the changes in the subchondral bony structure had disappeared, in two the appearances were unchanged, and in six partial healing had occurred, with

Table 1 Distribution of cases according to radiological findings

	Number	Medial location	Lateral location
ıgmented osteochondritis	10	6	4
ıltilocular cyst	7	6	1
litary cyst	3	2	1

One patient had changes on both sides of the talus, the total number of cases is 20

Table 2 Results at follow-up in relation to the site of the radiological finding in the talus history of trauma

	Symptomless	Mild pain	L
Medially in the talus	5	3	
Laterally in the talus	3	3	
History of trauma	4	2	
No history of trauma	4	3	

invasion of somewhat sclerotic bony tissue The contour of the surface of the bone was more even and smooth than preoperatively in three cases, unchanged in five, and in another five there was exacerbation, with collapse and a more rugged surface of the bone Since the treatment, six patients had developed mild *osteoarthritic changes, or else mild changes* had progressed

The radiological changes in the bone as well as on its surface and in the joint were identical whether the lesion was localized medially or laterally and whether or not there was a history of trauma In cases subjected to osteotomy of the medial malleolus, healing of the malleolus was uncomplicated, and the joint surface at this site is entirely normal

DISCUSSION

Osteochondritis dissecans affecting the talus is considered a rare condition According to Berndt & Harty (1959) it was first reported by Kappis (1922) Without knowledge of Kappis' publication, Wolff (1926), in Denmark, reported two cases, one of which had been diagnosed as early as 1916

From the literature up to 1957 Berndt & Harty (1959) collected a total of 151 cases. Of all these publications only three deal with more than four patients, viz, 13 (Ray & Coughlin 1947), 19 (De Ginder 1955), and 55 cases (Rodén et al 1953) The fairly large *series of 55 cases* was collected at the University of Stockholm (Karolinska Institutet och Sjukhuset) This, and the fact that 19 cases were found in 7 years in the Central Hospital, Naestved, woul indicate that the condition is not previously assumed Several authc Coughlin 1947, Rodén et al 1 pointed out that the radiologica may be difficult, and indeed this i by the present material

The discussion concerning the a osteochondritis affecting the talu differ from that concerning the kne of the ankle there is particularly t of the role of distortion trauma and transchondral fracture Eskesen (19 distinction between transchondral localized in the lateral angle of t cases) and osteochondritis dissecan to the medial angle of the talus or m of the trochlea (as described by M in nine cases from the literature pl his own) Myhre did not feel that t an aetiological factor Rasmuss published one case of osteoc localized laterally in the talus w occurred after a distortion trauma to Berndt & Harty (1959) the increasing tendency to accept the t traumatic genesis, and this view is O'Donoghue (1966) Rödén et a assume that changes in the lateral a talus are of traumatic origin, bu consider that this applies to medially changes. In the present material the probable traumatic cause in five c cases with changes in the upper lat the talus. The sixth patient had a h severe distortion trauma 7½ years p but the symptoms did not appear u later It is doubtful, but not ce

ation, that the trauma may have been itive On the other hand, a history of na is less common in cases having ges medially in the talus In the present nal only five out of 14 had a history of na. One of them is the above-mentioned of osteochondral fracture A cyst oped, but not until several years later might indicate that a trauma may have sustained several years previously out it being possible to adduce a definite onship

the present material patients having ges medially in the talus did not have or milder symptoms than those having ges laterally in the talus as found by n et al (1953).

already stated, the X-ray films showed chondritis, with sequestra and also locular cysts as described by Stougård 0) In several cases these cysts nunicated with the joint Lastly, solitary were found in three cases Several ors consider such solitary cysts a disease eneris (Crane & Scasano 1967, Stadil & 1970, Dashefsky 1971, Ogden & wold 1972, Paaby 1973), often called vial bone cysts The above-mentioned ors believe that these cysts are most ably of traumatic origin In this ection the possibility has been mentioned the pressure in the joint forces synovial down into an osteochondral fracture thereby prevents healing, and at the same a communication with the joint may ist. There was a hint of such a communica- in one of the present cases with a solitary in the upper medial angle of the talus.

the present material there was a striking ormity of osteochondritis and solitary with respect to symptoms and signs as as to operative findings. The three ents with solitary cysts were a woman 57 and two men aged 21 and 47 All had on weight-bearing, one also rest pain, but pisodes of locking or limitation of motion operation these cases exhibited soft, ermined cartilage Thus, there is a great to indicate that solitary synovial cysts and osteochondritis dissecans represent the same disease with different manifestation or at different stages of development.

The treatment, broadly speaking fairly uniform, afforded satisfactory results with relief from symptoms in eight out of 16 patients seen at follow-up after a minimum period of 6 months. Among the others, five had pain, but milder than prior to the operation, two had unchanged pain, and in one case talocrural fusion had been required Authors who have tried to assess conservative versus operative treatment (Berndt & Harty 1959, Rodén et al 1953) conclude that operation is definitely better Rodén et al (1953) restrict their operative indication to patients having symptoms. In the present material the diagnosis was made in all cases on the basis of symptoms

REFERENCES

Berndt, A. L & Harty, M (1959) Transchondral fractures (osteochondritis dissecans) of the talus. *J Bone Jt Surg* 41-A, 988–1020

Crane, A. R. & Scasano, J J (1967) Synovial cysts (ganglia) of bone *J Bone Jt Surg* 49-A, 355–361

Dashefsky, J H (1971) Post traumatic subarticular cyst of bone *J Bone Jt Surg* 53-A, 154–156

De Ginder, W L (1955) Osteochondritis dissecans of the talus. *Radiology* 65, 590–598

Eskesen, B (1942) En sjaelden intraarticulaer talusfractur *Nord Med* 16, 3436–3438

Kappis, M (1922) Weitese Beitrage zur traumatisch mechanischen Entstehung der "spontanen" Knospelablosungen. *Dtsch Z Chir* 171, 13–29

Myhre, H (1939) On osteochondritis dissecans trochleae tali. *Acta Radiol (Stockh)* 20, 272–275

O Donoghue, D H (1966) Chondral and osteochondral fractures. *J Trauma* 6, 469–480

Ogden, J A & Griswold, D M (1972) Solitary cyst of the talus. *J Bone Jt Surg* 54-A 1309–1310

Paaby H (1973) Solitary cysts of the talus. *Acta orthop scand* 44, 560–563

Rasmussen K. B (1945) Osteochondritis dissecans – et bidrag til spørgsmålet om aetiologien. *Nord Med* 28, 2088–2089

fragmented adipose tissue and a small amount of fatty fluid

The *histologic examination* revealed fragments [illegible]

adipose tissue showed regressive changes with small groups of foam cells, fibrosis and one fragment also included deposits of calcium

At follow-up 13 months postoperatively the patient had no complaints except for slight tenderness at the site of the heel incision Radiograms showed bone replacement of the lesion

Case 2 A 23-year-old woman experienced sudden pain in her left leg in December 1973, 6 months prior to admission She could not recall any trauma During the following months the ache persisted and was accentuated during and after walking Also a moderate swelling of the ankle and foot was observed

Radiography in January 1974 revealed an ovoid lytic lesion in the distal part of the tibia, with a maximum diameter of 6 cm, [illegible] within 1 cm of the ankle joint. Bone trabeculae and some calcifications [illegible] within the lesion which was well [illegible] without surrounding sclerosis (Figure [illegible] radiographic examination was repeated 1974 with the same result.

Diagnostic curettage with removal of [illegible] contents of the lesion was performed in [illegible] because chondrosarcoma was suspected

Grossly the specimen consisted of adipo[illegible] fragments and small pieces of bone

Histologically the material consi[illegible] dominantly of mature adipose t[illegible] as in Case 1 Small bone lamellae w[illegible] osteoblastic or osteoclastic activity within the adipose tissue No cartilage [illegible]

[illegible]

the lesion to be unchanged A fu[illegible] therefore performed with thorough rem[illegible] [illegible] contents of the le[illegible]

[illegible]

material revealed, as previously mature [illegible] tissue Areas of fibrosis and a moderate inflammatory reaction with inf[illegible] lymphocytes and plasmic cells were [illegible] probably reflecting a postoperative reaction

At follow-up 2 years and 8 months [illegible] operatively the patient, who worked walking all day, complained of moderate [illegible] and swelling of her ankle regions, most [illegible]



Figure 2 Case 2 Radiograph revealing an osteolytic lesion with some bone ridges and calcifications within the lower part of the right tibia

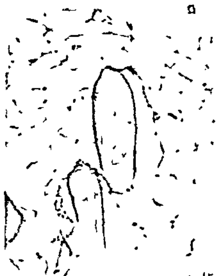


Figure 3 Case 2 Uniform [illegible] surrounding a few small lamellae of [illegible] H & E ×120

he left, operated side Clinically there was no ing or tenderness and no restriction of ankle ement. Radiograms showed that the lesion had replaced by normal bone.

CUSSION

• lipomatous tumours are rare occasional cases of liposarcoma primarily nating in bone have been described (e g wson 1955, Catto & Stevens 1963, lman 1964) The incidence of lipoma in bone is, according to Dahlin (1970), r 1000 cases of bone tumours. Also intra- ous angiolipomas and paraosteal lipomas been reported (Salzer & Gotzmann 1963, pp 1965) The most common location of osseous lipomas is the metaphyseal parts ng bones, including the present two cases, ut of 22 cases have been located at such : It is interesting that of the remaining five patients four presented with a lesion - calcaneus.

adiographically an intraosseous lipoma has appearance of a well-delineated osteolytic n within the marrow cavity, sometimes bone ridges and/or calcifications as in the cases described above It is noteworthy two out of three lipomas in the calcaneus rted previously showed a central sclerotic as in the present Case 1, which probably esponded to the regressive changes with osits of calcium found histologically (cf enzeller & Weitzner 1974, Poussa & mstrom 1976)

he histologic picture in the two cases described here was that of mature adipose tissue, not different from ordinary fat marrow and similar to that of a localized focus of osteoporosis (cf Dahlin 1970) The diagnosis of intraosseous lipoma can therefore not be based on the histologic appearance alone but must also include clinical information and radiographic appearance

Curettage and filling of the cavity with cancellous bone seems to be the treatment of choice if the lesion causes pain or a correct diagnosis cannot otherwise be made

REFERENCES

Appenzeller, J & Weitzner, S (1974) Intraosseous lipoma of os calcis. Case report and review of the literature of intraosseous lipoma of extremities. *Clin. Orthop* 101, 171–175

Catto, M & Stevens, J (1963) Liposarcoma of bone *J Path Bact* 86, 248–253

Dahlin D C (1970) Lipoma and liposarcoma In *Bone tumors General aspects and data on 3,987 cases* 2nd ed., pp 110–113 Charles C. Thomas, Springfield.

Dawson, E K. (1955) Liposarcoma of bone. *J Path Bact* 70, 513–520

Goldman, R L. (1964) Primary liposarcoma of bone Report of a case *Amer J clin Path* 42, 503–508

Krepp S (1965) Uber ein Knochenhamangio-Lipom. *Zbl. Chir* 90, 1674–1677

Poussa, M & Holmstrom, T (1976) Intraosseous lipoma of the calcaneous. Report of a case and a short review of the literature *Acta orthop scand* 47, 570–574

Salzer, M & Gotzmann, H (1963) Parostale lipome *Bruns' Beitr klin. Chir* 206, 501–505

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A CASE OF SEPTIC ARTHRITIS IN MULTIPLE JOINTS DUE TO *BACTEROIDES FRAGILIS* IN A PATIENT WITH RHEUMATOID ARTHRITIS

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A case of arthritis in multiple joints due to *B fragilis ssp* [illegible] described The *patient was a 55 year-old man badly disabled by* [illegible] arthritis. The patient's immune response to the isolated strain [illegible] and a significant titre reduction during the course of the [illegible] observed

[illegible] heterolog[illegible]

Key words polyarthritis, septic anaerobic infection Bacteroides [illegible]

Accepted 9 x.77

Anaerobes are nowadays isolated from most types of clinical specimens and this has raised the question of what role these bacteria play in different infections. Most anaerobic bacteria infecting human tissue are part of the normal *flora Anaerobes often act as opportunists* infecting patients in special risk groups with weak immunological defence The debilitated patient with rheumatoid arthritis appears to be unusually susceptible to bacterial infection and may develop septic arthritis which may be fatal if not adequately treated (Brit med J 1976) In 1969, Ziment et al made a review of the literature and found reports of 47 cases of septic joint infections involving anaerobes. Brorson et al. (1975) reported a case of pyogenic arthritis due to *Bacteroides fragilis* in a patient with rheumatoid arthritis with significant changes in antibody titres during the course of the disease.

In this report a patient is descri[illegible] septic polyarthritis due to *B fr*[illegible] *fragilis*

CASE REPORT

The patient was a 55 year-old [illegible] rheumatoid arthritis. He was badly d[illegible] had earlier been treated with steroids and [illegible] butazone. At the time of the *infection* [illegible] indometacin and salicylic acid.

The patient was *admitted to the hosp*[illegible] high fever which had lasted 3 days and [illegible] acute arthritis in his left shoulder Tr[illegible] penicillin V had been started. [illegible] treatment was added. Pus from the a[illegible] grew *B fragilis ssp fragilis* [illegible] responded well to treatment, but [illegible] rose as an abscess formed on the left [illegible] Lincomycin treatment was [illegible] arthritis developed in the patient's r[illegible]

elbow and there were signs of incipient ...one on his right upper arm. Subsequent ...s grew *B fragilis* resistant to penicillin. ...a change of treatment to clindamycin and ...idazole, as well as surgical drainage and ...rrigation of the affected joints with physio... saline, the patient recovered.

...atory methods

...iological procedures All specimens for ...: were transported to the laboratory in ...'s medium, or, when aspirated, in anaerobic ... culture bottles They were cultured ...ally using conventional laboratory tech-...as well as anaerobically using the Gas ...ystem (BBL, Maryland, USA) The methods ...ultivation and identification of anaerobic ...a described by Holdeman & Moore (1973) followed The subspecies of *Bacteroides* ...s were identified by fermentation tests, using ...I system (API, Plainview, N Y., USA). For ...vity testing the technique of Ericsson & ...s (1971) was used. The agar was the same as ...: original anaerobic cultivation. The bacteria ...carefully suspended in sterile saline and ...d on each plate. Excess suspension was ...ed and the plates were dried at 37° C ...gnated discs containing the antibiotics (AB ...c, Stockholm, Sweden) were applied to the ...and incubated for 48 h at 37° C in anaerobic ...sing the Gas Pak® system.

...specimens Seven blood samples were drawn ...the patient between October 1975 and July ... Sera were examined for antibodies against ...nfecting strain of *B fragilis ssp fragilis* ...d serum from five healthy laboratory workers, ...) years of age, was used as control. Serum ...es were frozen in small portions and stored at ...C until used.

Immunological procedures Indirect immuno-fluorescence test (IFL), tube agglutination and passive haemagglutination (PHA) were performed as described by Danielsson et al. (1974a) Fourfold or greater changes of titres were considered clinically significant (Danielsson et al. 1974b).

RESULTS

B fragilis ssp fragilis was isolated from the left shoulder joint, the left upper arm, the right elbow and the right knee. All blood cultures were negative The isolated strain was sensitive to doxycycline, erythromycin, lincomycin, clindamycin and metronidazole It was resistant to ampicillin, penicillin, gentamicin, cephalexin, sulphonamides and trimethoprim/sulphamethoxazole

Table 1 shows the immunological response against the isolated *Bacteroides* strain determined by three different methods. High titres were found with all methods at the time of the beginning and the peak of infection. The titres decreased significantly during the recovery of the patient. Control serum did not show any antibody titres against the *Bacteroides* strain used as antigen.

Four of the patient's sera were also tested against three heterologous strains of *B fragilis ssp fragilis* isolated in this laboratory from other types of infection. Only the IFL technique was performed The result is shown in Table 2.

...ble 1 Antibody titres in patient's sera against the isolated strain of Bacteroides fragilis ssp fragilis

	Date of serum sample							
	1975 7/10	1975 22/10	1975 5/11	1975 12/11	1976 14/1	1976 7/4	1976 24/6	Control serum
...ect immunofluorescence	160*	160	80	40	80	40	40	20
...: agglutination	320	ND†	80	ND	40	ND	ND	ND
...ive haemagglutination	320	160	80	20	40	ND	20	ND

...ciprocal titres
...)=Not Done

Table 2 Antibody titres of patient's sera against the homologous strain and three heterologous strains of B. fragilis ssp. fragilis

Strain no	Date of serum sample 1975 7/10	1975 5/11	1976 14/1	1976 24/6
Homologous strain	*160**	*80*	*80*	*40*
3559	80	160	80	20
3851	80	80	80	20
3686	160	160	160	40

* Reciprocal titres.

DISCUSSION

Though anaerobic infections are not common in patients with rheumatoid arthritis one has always to consider the possibility of an opportunistic infection in this risk group. Steroid treatment of these patients is a contributing risk factor. It is obvious that the isolated *B. fragilis* strain was responsible for the infection in this case.

Since the sensitivity to penicillin decreased during the therapy the treatment was changed to clindamycin and metronidazole. Most *Bacteroides fragilis* strains are resistant to penicillins. Unfortunately metronidazole was not available for sensitivity testing at the time of this study, but most *Bacteroides fragilis* strains isolated later in this laboratory were sensitive to this agent. Patients with bacteroides infections have been treated with metronidazole with success (Tally et al. 1975).

Elevated antibody titres against an organism show an engagement of the immunological defence indicating that the isolated strains play a role in the infection, as was seen in this case.

Table 2 shows that heterologous strains of *Bacteroides fragilis ssp. fragilis* cross-react with the isolated strain from this patient. Titres against the heterologous strains follow those against the homologous strain not differing more than one step upwards or downwards. Immunological methods will probably be of great value in the future in *establishing the role of anaerobes i[illegible]*

The IFL-technique seems to [illegible] factory of the methods we have used [illegible] study. It is fast and does not requ[illegible] bacterial cultures. When a *Bac[illegible]* infection is suspected serum from the p[illegible] could be immediately tested against a [illegible] number of strains. This would [illegible] clinician to obtain a rapid answer be[illegible] organism can be isolated from the [illegible]

REFERENCES

Brorson, J. E., Edmar, G. & Holm, S. E. [illegible] Some clinical immunological and [illegible] logical observations in a case of [illegible] arthritis due to *Bacteroides fragilis*. *Scan[illegible] infect Dis* 7, 222–224.

Danielsson, D., Kjellander, J., Perss[illegible] Wallensten, S. (1974a) Investigat[illegible] immune response to aerobic and [illegible] intestinal bacteria in a patient with [illegible] disease. In S. Persson, Academic Dis[illegible] Uppsala.

Danielsson, D., Lambe, D. W. & [illegible] (1974b) Immune response to [illegible] infections. In *Anaerobic bacteria [illegible] disease*. Eds. Balows, A., DeHaan, [illegible] Dowell, V. R. & Guze, L. B. Pr[illegible] Charles C Thomas, Springfield, [illegible]

Ericsson, H. M. & Sherris, J. (19[illegible]) [illegible] sensitivity testing. *Report of an [illegible] collaborative study*. *Acta path. [illegible] scand.* (B), Suppl. 217.

''nan, L V & Moore, W E C (1973) *aerobe laboratory manual.* Virginia Polytechnic Institute and State University, cksburg, Virginia, USA.
g article (1976) *Brit. med. J*, 6044, 9–1090
F P., Sutter, V L. & Finegold, S M (1975) Treatment of anaerobic infections with metronidazole *Antimicrob Agents Chemother* 7, 672–675
Ziment, J, Davis, A. & Finegold, S M. (1969) Joint infection by anaerobic bacteria A case report and review of the literature. *Arthr and Rheum.* 12, 627–635

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PROCEEDINGS OF THE SWEDISH ORTHOPAEDIC ASSOCIATION

Borås, May 12–13, 1977

EDITOR BO E NILSSON

GUEST LECTURE

DECREASED ABDUCTION OF THE HIP JOINT IN INFANTS

K Palmén
Falköping

In 206 infants, in whom CDH had not been detected in the neonatal period, a later diagnosis revealed a decreased abduction in no less than 127 cases. However, this condition is not always related to CDH Contracture of the adductors of the hip in infants is probably in many instances caused by habitual, supine – sideways position In Sweden, infants have been traditionally kept in the supine position. It could be demonstrated that 20 per cent of children kept in this position had a decreased range of abduction motion whereas only a few children, kept in the prone position, had a decreased abduction The range of decrease was 10–30° Radiograms of these children could be misleading in that the child is not in a correct position on the X-ray table Otherwise, the children's hips are radiologically normal A good method of preventing this symptom, which may be wrongly interpreted as CDH, is lying the child in the prone position.

MECHANICS AND SYMPTOMS FOLLOWING KNEE INJURIES

O Lindahl
Linköping

The occasionally poor relationship between objective findings and subjective symptoms in various orthopedic conditions is exemplified The anterior cruciate ligament does not by itself stabilize the knee joint in a sagittal direction Cruciate ligament surgery is a very doubtful procedure in that the relationship between the symptoms, the condition of the ligaments and the postoperative improvement has not been verified Objective measurements of the mechanical properties of the knee joint before and after surgery should be recorded in order to evaluate the results of surgery which may not necessarily [illegible] the opinion of the patient

MEASUREMENT OF SAGITTAL INSTABILITY OF THE KNEE JOINT [illegible] FUNCTIONAL POSITION

L-E Sylvin
Linköping

In 10 patients with a positive drawer [illegible] knee injury, the medio-posterior aspect of [illegible] capsule was tightened by a surgical p[illegible] described previously The subjective and [illegible] results were good Also, the sagittal [illegible] measured in 90° flexion improved. However [illegible] 1 year this variable did not differ greatly [illegible] preoperative measurement The cause of [illegible] crepancy between a lasting clinical imp[illegible] and a temporary improvement of joint [illegible] may be that the 90° flexion position is [illegible] for measuring the drawer-sign, since [illegible] and running knee flexion rarely exceed [illegible] Therefore, an instrument for [illegible] measurements of sagittal knee stability [illegible] degrees of flexion has been designed [illegible] *proved valuable in preliminary studies*

RESULTS OF SURGICAL REPAIR OF K[illegible] LIGAMENT INJURIES

P Surin & L. Ottosson
Borås

Thirty-three recent and 42 chronic knee [illegible] injuries were *re-investigated* 2–11 years [illegible] operation. The injuries were in many [illegible] combined, *most commonly* anterior cruci[illegible] medial collateral ligament ruptures. A [illegible] surgical procedures was involved. There [illegible] significant positive correlation between [illegible]

ł subjective stability The subjective improve-nt was related to the quadriceps force After ᵻrative treatment recent injuries were nificantly more often improved than chronic ᵌs. All residual symptoms, except for the feeling instability, were more common in those ients who had been operated on for chronic uries. Radiological signs of arthrosis increased h the period of observation in chronic cases not in recent cases. The various qualities of tability are related – one single measurement of bility is not relevant. Early operation and total air of all structures is recommended.

TE RESULTS OF PARTIAL PATELLAR
NDON TRANSPOSITION FOR LATE
PAIR OF ANTERIOR CRUCIATE
GAMENT RUPTURE
Dolk, S Hallberg & U James
.bro

'wenty-five patients operated on with ᵻnstruction of the anterior cruciate ligament, ᵻg a transplant obtained from the patellar 'lon, were re-investigated after an average ᵀrvation time of 33 months. Twenty-three of patients considered themselves improved in e of the fact that more than half still had a tive drawer-sign. There was no significant 'tionship between the results with regard to 'ective knee stability and subjective improve-nt. With increase in the period of time from ᶠry the results tended to deteriorate. The time rval injury-operation also appeared to be of 'ortance.

SULTS FOLLOWING CRUCIATE

.ea

'en cases operated on using a patellar tendon ᵻsplant without bone attached and 12 with ᵻched bone were re-investigated. The follow-up ᵻuded arthroscopy The drawer-sign and ᵻtional motion of the knee were recorded The bility and the subjective results were better in ᵻents with a bone-tendon transplant The umulated percentage of residual symptoms was A relationship existed between the drawer-sign l the patient's feeling of instability hroscopy revealed that 11 of the 12 bone-ᵻdon transplants remained in a good position ᵻreas six out of ten without bone, although in a rect position, seemed to have loosened newhat.

RECONSTRUCTION OF THE ANTERIOR CRUCIATE LIGAMENT
E Eriksson
Stockholm

Four modifications of Jones' procedure were compared. Eighty per cent of the knee joints were stable at the 1-year follow-up, using a modification that included a new drill guide A detailed description of the operative technique is published in *Injuries of the Ligaments and their Repair*, ed. by G Chapchal, pp 130–142, G Thieme, Stuttgart, 1977

RECONSTRUCTION OF INVETERATE POSTERIOR CRUCIATE LIGAMENT INJURIES
A Stenström
Lund

Five patients, all with a posterior drawer-sign, were operated on The semi-tendinous tendon with bony attachment was used for reconstructing the posterior cruciate ligament in its original position Four of the patients had improved with regard to instability, subjectively and objectively, three could participate in soccer, and one (a woman) did not improve

ACUTE ARTHROSCOPY
E Eriksson
Stockholm

Fifty consecutive acute knee injuries were examined arthroscopically The injuries, 35 total or partial anterior cruciate ligament injuries, five bucket handle and four other meniscal lesions, two radiolucent chondral loose bodies and two cases of pigmented villo-nodular synovitis, could be easily diagnosed and treated while under the same anesthesia Acute arthroscopy is the quickest and most reliable method with which to obtain an accurate diagnosis.

KNEE INJURIES IN SOCCER PLAYERS
A Roaas & G Andersson
Goteborg

One hundred previously active or still active soccer players, aged 30–40, were compared with 108 age-matched controls, selected to represent the male population of the city of Göteborg A history of knee injury was found in 56 per cent of the football players, and in 17 per cent of the controls. Knee symptoms were present in 65 and 34 per cent, respectively The most common injury in both series was rupture of a semilunar

cartilage – 29 per cent in the football players, 6 per cent in the controls. Sixteen per cent of the football players had ligamentous injuries as compared with 4 per cent in the control series. Instability was found in 18 knees among the football players and in 16 knees in the control series. Reduced joint space was found medially in four subjects, all soccer players.

COMPARATIVE STUDIES OF QUADRICEPS TRAINING MODELS AFTER KNEE SURGERY

L Peterson, G Grimby, E Gustavsson & P Renström
Göteborg

The effect of quadriceps exercise was tested in *three groups of patients after knee injury and* operation one group used an isokinetic training device, one group a quadriceps exercise table and *one a standard home program* The exercise program was carried for a period of 6 weeks, three times a week. In all groups the quadriceps force *was improved by the exercise programs. The im*provement in quadriceps force was greatest, both dynamically and statically, after isokinetic exercise.

THE SWEDISH NATIONAL KNEE ARTHROPLASTY PROJECT – A PROGRESS REPORT

M Grubor, G Bauer & A Lindstrand
Lund

Since 1975, 824 cases have been reported so far to the central register Nine per cent were post-traumatic, osteonecrosis etc., whereas the remainder were evenly divided between osteoarthritis and rheumatoid arthritis patients. The compartment sliding type of prosthesis has been the most frequently used, with the Marmor prosthesis being the most popular Complications have been recorded in 10 per cent of the cases. Deep infection, as a late complication, has so far been recorded in only six cases, of which four occurred after implantation of a hinge prosthesis. The early mortality was 0 25 per cent.

ROENTGENOGRAPHY OF KNEE ENDOPROSTHESES

S O Ahlbäck & J Rydberg
Stockholm

The radiograms of the patients involved in the national project are being reviewed centrally with classification of the preoperative roentgen diagnosis. The basic concept is that an engagement of both the lateral and medial compartments of the joint should be ... arthritis rather than arthrosis. It is recommended that gonarthrosis be classified according to localization of cartilage destruction and distribution of osteophytes. Also, a roentgenographical appearance of the types of knee prostheses is being prepared, will, in the future, serve as a guide radiologists.

TWENTY-FIVE YEARS EXPERIENCE OF ARTHROPLASTIES

B Walldius
Stockholm

A personal experience of arthroplasties 1951 was presented. Based on experience with use of cement since 1953, it is suggested that endoprostheses should be designed to stay and to function without cement. Any foreign body will be surrounded by a layer fibrous tissue An endoprosthesis can mechanically arranged in order to permit degree of elastic deformation in this fibrous without running the risk of loosening. The types of knee prostheses and the reasons for sequent modifications were described. The type has a built in capacity for rotation.

RECONSTRUCTION OF THE MEDIAL *TRANSVERSAL PATELLAR* RETINACULUM IN CASES OF LATERAL TILTING PATELLA

F Tidestrõm
Linköping

The medial third of the patellar ... together with a part of the tibial tuberosity dissected from below up to a 45° degree medially inclined line on the middle of the patella. It is then turned medially, drawn below the end of the adductor magnus tendon and ... itself, pulling the patella medially This procedure was applied in cases of laterally tilting patella order to prevent sideways movement. In ... 11 patients, aged 15 to 52, this procedure ... followed by improvement of the condition.

SYNOVIA – A CRYSTAL BALL FOR ORTHOPEDIC SURGEONS

P H Widmark
Malmö

Syn (like) – ovia (egg) – analyses in the ph... *ing microscope* is now in fashion. However

na glucose content is also of interest A value ding the "normal" serum value will fre- tly unmask a latent or manifest diabetes tus! In postoperative hemarthrosis in philic, gouty or rheumatoid joints there often a high intra-articular pressure, low pO_2 high pCO_2 level and a decreased pH, all of h changes are unfavorable for the metabolism nt tissues. Such joints, therefore, should be tured and frequently aspirated.

DIAGNOSIS OF DEEP INFECTION ER TOTAL HIP REPLACEMENT

'arlsson, G Josefsson & L. Lindberg
no Gävle and Lund

he diagnosis of early infection following total replacement is usually simple but difficulties be encountered in cases with symptoms ring months or years postoperatively In cases, signs and symptoms, simple ratory methods and radiographic examinations ce for the diagnosis. The most prominent ires are pain on walking, located in the groin thigh, rotational pain, elevated ESR and graphic bone resorption. In doubtful cases, imetry and, rarely, arthrography may be of For the definitive diagnosis, aerobic and robic cultures of deep biopsies are required. It to withdraw antibiotics several weeks r to biopsy

MATOGENOUS INFECTION

he incidence of hematogenous infection in l hip arthroplasties has been calculated to be –0 3 per cent. The onset of infection is rapid h signs and symptoms similar to other forms of tic arthritis. In 16 cases described in the rature and five cases of our own, infection rted 3–66 months (mean 26) after operation. e causative microbes were *staphylococcus reus, E coli, proteus mirabilis, beta eptococcus* and *pneumococcus* In almost all es, removal of the prosthesis became necessary d four patients died At present, a thorough bridement, followed by irrigation drain and to be the treatment of choice

COBALT ALLERGY – A CAUSE OF ENDOPROSTHESIS LOOSENING

A Heijer, U James, H Kogler & K Undeland
Uddevalla and Örebro

Seven cases are presented in whom cobalt allergy is suspected as a factor contributing to poor results of knee endoprosthesis. In four of the cases, the prosthesis had to be removed. There were negative cultures, at least two, anaerobic and aerobic, in all cases, and four had a skin rash in the knee region. Four cases had cutaneous tests, positive for cobalt allergy All seven cases were metal to metal endoprostheses (Walldius and Guepar) It is suggested that metal to metal articulations be avoided, and that epicutaneous tests for metal allergy be included in the pre-operative procedure

BRACHYMESOPHALANGIA AND OSTEOCHONDRITIS DISSECANS

B Lindén
Malmö

This is a condition which combines hypoplasia or even aplasia of the middle phalanges of the hands and/or the toes with osteochondritis dissecans in the carpo-metacarpal joints. The syndrome was discovered in one patient, who presented with locking in a metacarpo-phalangeal joint. The family of this proband consisted of 27 individuals, 17 of whom were investigated. Ten of these had the syndrome, and out of the remaining 10, another 4 possibly had similar changes. The heredity is autosomally dominant. Those affected had no other malformations or clinical signs and the syndrome had rarely caused clinical symptoms.

THE EFFECT ON ARTICULAR CARTILAGE OF INTRA-ARTICULAR INJECTION OF OSMIUM TETRAOXIDE AND RADIO-GOLD IN EXPERIMENTAL ARTHRITIS

Å Ahlberg, A Henricson, H Telhag & F Wollheim
Malmo

Antigen-induced arthritis was produced in 30 adult rabbits, using ovalbumin. After 4 weeks 10 rabbits received 0 3 ml 1 per cent Osmium tetraoxide, 10 rabbits 100 µCi ^{198}Au intra-articularly and 10 served as controls. In addition, 10 rabbits without arthritis were treated with osmium and 10 with ^{198}Au. Light microscopy showed severe destruction of articular cartilage in the osmium-treated animals, worse than in the controls On the other hand, the degree of destruc-

tion in the ^{199}Au-treated animals was less than in the controls and the osmium animals. In all the non-arthritis animals light microscopy was normal regardless of treatment. Autoradiograms (^{3}H-thymidine) showed injury to the cartilage in all groups

TENODESIS IN RECIDIVOUS ANKLE SPRAINS USING THE SHORT PERONEAL TENDON

L Ottosson
Borås

Lateral ankle instability was treated with peroneal tendon tenodesis. Forty-two patients, operated in this manner, were followed up, on average, 5 years after surgery Most of these patients had a distinct trauma in their history with instability, repeated sprains and, periodically, pain at rest The procedure caused no complications and was followed by improvement in all but three of the patients. The most common persistent symptom was lateral swelling in 14 cases. Four patients were unable to do physical exercise after surgery It was demonstrated that tenodesis, using the tendon in its normal position, has a good stabilizing effect on the ankle joint.

EXTIRPATION OF TUMORS LOCATED NEAR THE THORACIC CAGE

B Stener & G Markhede
Göteborg

A method is described by which the external thoracic fascia, the external intercostal muscles and the periosteum of the external surface of the ribs can be included in the specimen as a continuous wall of healthy tissue on the deep side of the tumor This technique has been used in 11 patients, nine of whom had undergone one or more inadequate operations earlier Eight patients had malignant tumors, three an extra-abdominal desmoid. In one of the latter patients, in whom a recurrent tumor was adherent to the rib periosteum, the method was unsuitable In the other patients, the method appears to have been adequate for local control of the tumor

WHEN SHOULD OS CALCIS FRACTURES BE OPERATED ON?

O Thorén
Vanersborg

In the past, it has been demonstrated that cases with severe displacement and with a Böhler angle of 0° or less are more successfully treated surgically than conservatively Using [illegible] 32 suitable cases were operated o[illegible] 2 days after the injury The o[illegible] by a lateral incision, the posterior aspect of [illegible] joint being elevated and [illegible] for support The previous concept [illegible] dications for surgery was supported by the [illegible] of this series.

WORKING CAPACITY FOLLOWING McMURRAY OSTEOTOMY

M Yllö
Skövde

Thirty-seven patients, 27 men and [illegible] with coxarthrosis, in many instances [illegible] were operated on with a [illegible] according to McMurray The follow-[illegible] was at least 2 years. The age range for [illegible] was 24–58, and for men 36–64 [illegible] demonstrated that 25 patients were [illegible] heavy work whereas 12 were doing light [illegible] Twenty-seven went back to work after the [illegible] tion. Seventeen were able to do the same [illegible] work after operation as before whereas [illegible] had to change to a lighter job Ten patients [illegible] not go back to work.

BONE MINERAL IN BALLET DANCERS

S Andersson
Malmo

In professional ballet dancers, the bone [illegible] content was measured in the cancellous [illegible] the proximal end of the tibia. The [illegible] significantly increased as compared with [illegible] ballet control population, the mineral [illegible] being, in many instances, so great that [illegible] above the range of normative data. As ex[illegible] was also given of a severe post-tra[illegible] penia, following a minor foot injury to a ba[illegible]

LOSS OF BONE MINERAL AFTER TI[illegible] SHAFT FRACTURE

S Andersson
Malmo

After a tibia shaft fracture the bone [illegible] content of the distal end of the tibia [illegible] decreased. The average loss was about [illegible] cent. Within the first year there was [illegible] recovery of bone mineral but the original [illegible] was never attained. There was no difference [illegible] this regard between 13 patients treated [illegible] long leg plaster cast and crutches at [illegible] with 14 treated with a functional plaster [illegible]

ht bearing with a free knee joint and no ort.

S OF BONE MINERAL AFTER AMENTOUS KNEE INJURIES

nderssson
mo

he bone mineral content in the proximal end e tibia was measured in patients with clinical s of ligamentous knee injuries from the day of injury and over a period of 1 year There was pid loss of bone mineral 7 per cent in those ents who were treated with an ace-bandage and mobilized as soon as possible, and 14 per in patients operated on with repair of the ments and postoperative plaster cast for 6 ks. No signs of restoration of the lost bone eral were noticed in any of the groups.

THOPEDIC HEALTH SURVEY OF YEAR-OLDS IN STOCKHOLM

Spangfort
ddinge

bout 5 000 69-year-old men and women, dents of the city of Stockholm, who had not n admitted to institutions, were surveyed with ard to orthopedic conditions. Sixty per cent of women and 50 per cent of the men had sub-ive symptoms from spine or joints, of which fifth were classified as severe However, only 3 per cent had an obvious orthopedic condition uiring referral for orthopedic treatment ereas 6–7 per cent had symptoms which bably could be managed in a general practice e survey did not support the concept of a large lent" need for orthopedic services in this tion of the population, nor that routine health veys of the elderly by orthopedic specialists ld be justified.

CHNICAL FAILURES WITH THE ENDER AILING PROCEDURE

Hult & M Nilsson
ockholm

Technical difficulties were encountered in 62 t of 920 cases. The nails slipped in 31 cases in , owing to compression of the fracture causing e nails to slip and interfere with the knee nction, and, in 15, because of poor fixation with slocation of the fracture All 31 cases were re-erated on in 6, the nails were removed after the acture was healed whereas slipping in conjunc-on with fracture dislocation could not be successfully re-operated using Ender nails. Perforation of nails into the acetabulum occurred in 19 cases but caused little discomfort to the patients. In nine cases, nails were displaced outside the femoral neck and head. All fractures, including those with technical failures, healed satisfactorily

FRACTURE ORTHOSES

D Mozer
Borås

A fracture orthosis should fulfil the criteria of being available to supply a fracture at short notice and without time-consuming shop work. Thermoplast can be moulded on the leg The orthosis is cut longitudinally leaving a gap of 1 cm and then attached to the limb under pressure Also, fixtures are attached with thermoplast These orthoses are best suited for thigh and below-knee fixation. The main advantages are low weight, easy handling, radio-translucency, immediate weight-bearing and control of compression In a series of 30 patients, the opinion of the patients regarding this bandaging technique was very positive.

THE TULIP PROSTHESIS

O Henriksen, G Marsch & B Persson
Karlskrona and Lund

In the tulip prosthesis a cushion filled with tiny plastic balls is moulded onto the stump The air is evacuated by a pump from this "air splint", which then serves as a semi-rigid provisional stump support which may be inserted into a standard adjustable early walking aid and secured with four "petals" (hence the tulip!). In a series of 13 below-knee amputees aged 37–88 this method greatly improved the results of early postoperative walking exercise Also the physiotherapists were able to handle this phase of rehabilitation independently without involving the brace shop in the individual cases.

ASPECTS OF SENSORY FEEDBACK FROM MOTORIZED PROSTHESES

P Herberts, L. Korner & A Anani
Goteborg

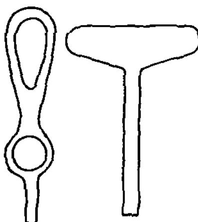
Afferent electrical nerve stimulation was carried out, using a percutaneous method for intraneural stimulation of nerves in the amputation stump of below-elbow amputees and by sensory nerve stimulation in non-amputees. It was found that frequency or amplitude modulated stimulation

after a limited training could convey information on about five to six discrete levels with a *rate of* correct recognition of greater than 80 per cent and with an amount of transmitted information of 1 80–2.05 bits *per symbol.* These results have encouraged further work in order to develop a motorized prosthesis with this kind of feedback system.

ERGONOMICALLY IMPROVED RETRACTOR HANDLES

H Ekstrom & O Lindahl
Linkoping

On the basis of ergonomic considerations, the traditional retractor handle designed about 1890 has been replaced by a new handle (Figure) It could be demonstrated by experiments and practical tests that the new handle offers a con siderable improvement by distributing the pressure of the tool more evenly and reducing the muscle force needed to maintain a constant traction at a level which is more comfortable for the surgical assistant



THE SCAPULO-COSTAL SYNDROME

L. Blomberg
Borås

Tenderness of the superior angulus of the scapula, *radiating pain to the neck and sometimes* to the arm, and dysfunction of the levator scapula muscle and to some extent the rhomboids, are characteristics *of the scapulo-costal syndrome.* Four patients were described. The etiology seemed in all cases to be a sprain of the arm and shoulder *In one case with very severe pain after*

SYMPOSIUM – OCCUPATIONAL ORTHOPEDICS

INTRODUCTION I

A Nachemson
Goteborg

The locomotor system is the most com[illegible] of occupational disability with disorders of the back. Our knowledg[illegible] relationship between working conditions [illegible] in the back is incomplete It is therefor[illegible] to devote much more work to and take interest in occupational orthopedics.

INTRODUCTION II

G Danielsson
The National Board of Occupational Sa[illegible] Health, Stockholm

With the reform of July 1 1977 in Swe[illegible] definition of occupational injury will be e[illegible] to include conditions not necessarily ca[illegible] accident The problems involved in p[illegible] orthopedic conditions will therefore be important in the future Today depart[illegible] occupational medicine are being establ[illegible] over the country and most of the healt[illegible] are being covered It is desirable to [illegible] decentralize these activities. An im[illegible] objective of occupational medicine is [illegible] health care in general into closer conta[illegible] working conditions. Orthopedics will [illegible] respect, be one of the most important branc[illegible] medicine

EXAMPLES OF INJURIES TO THE BAC[illegible]

A Nachemson
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Between blue collar and white colla[illegible] there is no difference in the incidence of pa[illegible] the back. The importance of psycho-social [illegible] for low back incapacity is well docum[illegible] Working conditions, particularly jobs [illegible] lifting strength, stooping positions or deman[illegible] maximal physical effort are of major impor[illegible] in this context. With electromyography [illegible] pressure measurements it is possible to [illegible] optimum sitting working position in patients [illegible] severe back pain. Patients with sciatica [illegible] dominantly affected by bending [illegible] rotating movements. However in other [illegible] many patients with back pain [illegible] locomotor capacity comparable with normal [illegible]

It has been demonstrated that the [illegible] of the nucleus pulposus is poorly supplied [illegible]

content of oxygen and glucose In the line, between the nucleus and the annulus, ig ruptures may occur at an early stage of generative process. These changes may be pronounced if the disc is subjected to static of a long duration

IODS EMPLOYING TROMYOGRAPHY FOR IECHANICAL STUDIES

defors
ataverken, Goteborg

sical load presents the most common aint among Swedish workers, as far as work nment problems are concerned. Quantitative ds for studying physical work are needed, MG methods are of major potential interest is regard. Static work is accompanied by es in the spectral composition of the EMG, itive of decrease in muscle fiber conduction ity The quantitative interpretation of the changes is greatly facilitated by using intra-ular single wire electrodes for signal pick- This method is also applicable in field studies e shop floor

THODS OF BACK LOAD SUREMENTS

rtengren
borg

w objective methods for measuring forces e the body are currently available Examples recordings of intra-discal pressure and of -abdominal pressure Monitoring of electric back muscle activity using surface or utaneous electrodes is also useful ntitative electromyography has been applied in studies of working postures in the laboratory as well as on the shop floor The myoelectric signal amplitude is a predictor of muscle force, and the changes in the signal power spectrum parallel localized muscle fatigue It has been demonstrated that the myoelectric activity and the intradiscal pressure of the lower back increase linearly with the load on the spine The method of weight-lifting – back-lifting or leg-lifting – seems to be less important whereas the distance between the weight and the body is more important for the load on the back.

SHOULDER PAIN IN ARDUOUS INDUSTRIAL WORK

P Herberts
Goteborg

Static work was studied by means of quantitative electromyography from muscles of the shoulder of welders in a ship-yard. The myoelectric spectral development indicated that localized muscle fatigue was common in prolonged overhead work, especially in the supraspinatus muscle By means of clinical examination, soft tissue radiography and quantitative electromyography, the effect of this type of industrial work was evaluated in welders with typical shoulder pain. The study revealed that the older workers have a chronic tendinitis of the rotator cuff The supraspinatus muscle was shown to be consistently fatigued during overhead welding It is believed that this is an important [illegible]

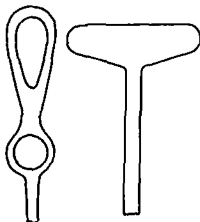
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PROCEEDINGS OF THE FINNISH ORTHOPAEDIC ASSOCIATION

Kuopio, Finland, May 20, 1977

EDITOR A. ALHO

INCIDENCE OF THROMBOEMBOLISM IN ELECTIVE HIP SURGERY

O Suomalainen
University Central Hospital, Kuopio

Thromboembolic complications were analyzed in a series of 38 total hip replacements, 25 intertrochanteric osteotomies, and three endoprosthesis applications. Warfarin was used for prophylactic anticoagulation Thrombosis was [illegible]

simultaneously using xenon[illegible] Positive cases of thrombosis were also examined by contrast venography A total of 23 (35 per cent) deep venous thromboses were diagnosed using I^{125} fibrinogen nine of these (14 per cent) were bilateral Radionuclide venography using Tc^{99m} gave frequencies of 26 (39 per cent) and 7 (14 per cent), respectively A clinical diagnosis of thrombosis was made in 16 cases (24 per cent) The same frequency, 24 per cent, was obtained by contrast venography Ventilation perfusion lung scanning revealed nine lung emboli (14 per cent) Five patients had clinical symptoms of pulmonary embolism

LUMBAR SPINAL STENOSIS

V Rehnberg
University Central Hospital Kuopio

Between April 197[illegible] and No[illegible]ember 1976 a total of 29 patients were operated on for spinal stenosis at Kuopio University Central Hospital This accounts for 13 9 per cent of all disc operations performed during that period The average age of the patients was 47 8 years [illegible] to 66 years). Preoperatively, back and leg pain were the most common complaints, both occurring in about 90 per cent of the series. Nineteen patients (65 5 per cent) had cauda equina [illegible] intermittent claudication.

A positive Lasègue (SLR) sign was fo[illegible] patients (41 6 per cent). The [illegible] neurological disturbances found were the [illegible] of the Achilles reflex (12 patients), a de[illegible] the power of the toe extensors (8 pa[illegible] hypaesthesia corresponding to dermato[illegible] S1 (13 patients in all). According to the [illegible] findings five (17.2 per cent) of the pa[illegible] considered to have congenital stenosis, [illegible] stenosis in the rest was mainly degene[illegible] origin.

The operation consisted of a decomp[illegible] laminectomy, usually performed on two l[illegible] no case was spinal fusion performed. The [illegible] postoperative follow-up was 13.3 mont[illegible] results were excellent or good in 65.5 pe[illegible] the patients.

TREATMENT OF TROCHANTERIC FRACTURES OF THE FEMUR USING ENDER METHOD

V Rehnberg & S Peltari
University Central Hospital, Kuopio

Intramedullary Ender nails have been [illegible] the treatment of trochanteric fractures of [illegible] in Kuopio since March 1976. Reference is [illegible] the first series of 27 patients treated by [illegible] method. The mean age was 77 years. The [illegible] duration of the operation was 4[illegible] blood loss varied from minimal to [illegible] One patient died postoperatively [illegible] myocardial infarction.

The fact that the distal ends of the na[illegible] beginning were not fixed with screws [illegible] most of the complications. In four [illegible] or more of the nails had to be removed [illegible] they slid downwards. In one patient [illegible] non-union and in another wound [illegible] case a reoperation had to be performed [illegible] Jewett nail. Minor sliding of the nails [illegible] pain at the site of insertion and [illegible] caused healing of the fracture in a [illegible]

Another healed in a rotational malposi-

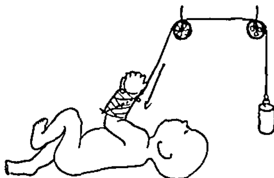
:nder method has three advantages it is ıically difficult, it reduces operative stress minimum, and allows immediate ·ative weight-bearing

RY TREATMENT OF BRACHIAL S PALSY WITH DYNAMIC 'ION

ell

f Paediatric Surgery, University Central l, Kuopio

ıes of 23 newly born babies with brachial palsy were treated with dynamic traction litional physiotherapy (see Figure) Eleven ıneteen cases of C_5–C_6 spinal root involve- :rb's palsy) recovered in 1–5 months (mean ths), a further four cases recovered in months (mean 16 months) Two recovered t treatment and another two developed ant handicaps, as did a further four cases C_5–C_7–C_8 involvements. One severe case vent surgery as primary treatment.



Dynamic traction effectively activates the paretic arm and this regimen is easy to carry out at home, too As it gives evidence of the trend in recovery more rapidly than any other current method of treatment, it reveals resistant cases early enough to enable surgical correction In all cases of brachial plexus palsy, dynamic traction treatment is indicated because the extent of involvement does not necessarily correlate with the speed and extent of recovery

›p. scand 49 113–120, 1978

.OGENETIC STIMULATION BY EXTERNALLY IED DC CURRENT

ARSKI*, D DEMETRIADES† & A MACKENZIE†

sity of Waterloo, Mechanical Engineering Department, Waterloo Ontario, and
eal Children's Hospital, Montreal, Quebec, Canada

A new, simple, safe and noninvasive technique for the electrical stimulation of fracture healing is introduced. The safety and the simplicity of the technique makes it possible to apply it almost immediately to clinical experimentation. Electrodes were applied externally to the fractured site producing current across the limb. It was observed that the current density changes the volume of callus and affects the direction of the trabecular orientation. When the trabecular orientation is completely changed from longitudinal to transverse, the larger volume of callus does not compensate for the loss of strength as compared with the callus on the control bone

Key words osteogenesis callus, bioelectricity bone

Accepted 13 ix 77

well established fact today that DC and ectrical microcurrents have an effect on genesis. The phenomenon was first ved by Yasuda et al (1954), Iida et al) and Noguchi (1957), later by many rchers in North America and Europe and anding results were reported by Bassett (1964 and 1975). It is also generally ted that stimulating currents range een 5 μA and 25 μA, higher currents may uce deleterious effects.

ie mechanism of electrical stimulation still uns a matter of conjecture, however, ral hypotheses attempting to describe ations in the electrically stimulated tissue ronment have been proposed It is only onable to accept the fact that in the ence of ionic currents, various effects of trolysis must be present (Pilla 1974) Thus t investigators have reported, on the basis n *vitro* (Becker & Murray 1970) and *in* › (Noguchi 1957 and Friedenberg et al 0) studies, higher osteoblastic activity on the cathode side and osteoclastic on the anode side The ionic byproducts have also been observed in the tissue surrounding both the anode and the cathode The puzzle which still remains unchallenged is cellular behaviour between the cathode and the anode. The conductivity in the soft and the hard tissue is predominantly ionic. Thus there are cations and anions moving through the tissue in the presence of an electrical current Assuming that there is always a balance of positive and negative ions, the cellular environment will remain unchanged However, there is a high probability that in the path of ions there exists selective adsorption of some ions and possible semiconductive properties of tissue (Digby 1966, 1974) The combination of the above parameters and differences in the ionic mobility would produce, according to Digby (1974), local changes in pH and thus affect precipitation of calcium salts which is highly dependent on pH This would change the immediate cellular environment even far

removed from the electrodes. It is also reasonable to speculate that the change of the cell's environment would control its metabolic activity (Parseyian 1974)

Assuming that the above rationalization is true, the following two simple conclusions can be established

1 The direction of the microcurrent does not have to be across the fracture site or parallel to the long axis of a bone, the way it has been attempted by Yasuda et al (1954), Iida et al. (1956), Bassett et al (1964, 1975), Becker & Murray (1970, Kraus & Lechner (1972), Levy (1974), Haas (1963), etc.
2. The specified magnitude of the current in electrical stimulation is an insufficient parameter It would be more desirable to know the current density in the stimulated region

METHODS

On the basis of the above conclusions, a new technique of electrical stimulation was designed. were attached externally to the skin of fractured limb using ECG gel for better coupling and the electric current density was estimated from the model illustrated in Figure 1

The complexity of the model illustrates the difficulty of the task, especially since it was not the resistance of the tissue which was needed. In order to estimate current density, the resistivity of all elements must be known. Clearly it is not possible to obtain this information, therefore exp methods should be used ' in mind that the current density would chang the thickness of a limb and the proportion various kinds of tissue in it.

MATERIALS

Three consecutive series of 12 white rabbits weighing between 3 and 4 pounds used. Prior to the actual experiment, the resistivity of various tissue components measured *in vitro* and *in vivo* An estimate made of the magnitude of current to be across the limb of a rabbit which would approximately an equivalent of the between implanted electrodes used in experim of previous investigators. In order to estimates, an insulated stainless steel wire bared end, was implanted at the osteotomy produced in the radius of the experimental External electrodes made from stainless thumb tacks, having a contact area of were applied with ECG gel to both sides osteotomy A 10-volt power supply prod 150 µA was connected to the electrodes current output was monitored from the wire at weekly intervals for 3 weeks. The 8 µA remained unchanged during the whole The result was disappointing since it was that the current would diminish with progressive growth and calcification of the However, the value of 150 µA, resulting theoretical current density at the site of of 123 µA/cm², was assumed to be close purpose of the first experiment The actual density inside the limb still remained a conjecture

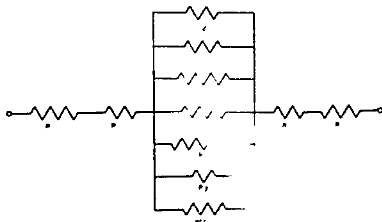


Figure 1 Electrical model fractured limb R, and resistance of the skin, R, R, are the respective muscle, connective ligaments, periosteum haematoma et

RESULTS

Experiment 1

Bilateral osteotomies on the radii of twelve rabbits were produced using a 0.05" thick flat saw. After a 1 day postoperative recovery period, electrodes were applied externally to the radii, one pair without an electric current and the other connected to a power supply. Electrodes were positioned in such a way that the current was directed through the osteotomy site. Animals were placed in restrainers and stimulated electrically with 123 µA/cm² for 3 hours every day for 14 days. After 14 days, animals were sacrificed with an overdose of anaesthetic and the bones were examined for callus formation at the control and experimental sites. Two weeks of healing time proved insufficient to form a fully calcified callus. Most specimens exhibited cartilaginous gaps in the centre of the osteotomy separating the calcified callus. In six of the experimental bones and in two controls the osteotomy was completely bridged by fully calcified callus. Since mechanical testing, with the exception of the latter eight specimens, would not produce any results, only the size of the formed callus was examined. The bones were separated at the osteotomy and photomicrographs on the macro attachment of a micrograph were taken, showing the cross-sectional areas of the formed callus. Upon evaluating the results, it was found that the cross-sectional area of the callus of the stimulated bones was 27 per cent larger than the control side.

Experiment 2

It was evident that the postoperative healing time was not sufficient to produce fully calcified callus, therefore the second group of animals was stimulated with the same current density for 21 days.

All bones from the stimulated and controlled sides had rigid unions with fully calcified calluses. The ends of the radii were mounted in the resin for tensile tests and stored in saline solution at 0 C. The results of the tensile tests were completely opposite to the expected values. The tensile strength of the stimulated bones was much *lower* than on the control side and the callus was much thicker.

At this stage, it was postulated that the current density had been over-estimated and therefore the opposite adverse effect was obtained for the same reason as observed in the fully invasive techniques by Pilla (1974).

Experiment 3

The third group of animals was stimulated also for 21 days but the applied current was reduced to 50 µA, resulting in a current density of 41 µA/cm². This treatment produced stronger and less bulky callus on the stimulated side.

The results of mechanical testing for all three experiments are summarized in Table 1.

DISCUSSION

The interpretation of the results is reasonably simple. Experiments 1 and 2 indicated that the current density of 123 µA/cm² definitely produced a much more bulky callus than on the control side. The strength of the callus however was lower on the stimulated side. The comparison of values for the Ultimate Tensile Strength improved the level of significance of difference to 0.39 indicating that the quality of callus was also poorer. The larger volume of callus on the stimulated side was not able to compensate for the reduction in strength. Reducing the current density to 41 µA/cm² reversed the results. Although the level of significance of the load to fracture was poor, the quality of callus was better resulting in a significant improvement in strength (UTS) on the electrically stimulated side.

Based on the above observations, it is not possible for this pilot project to claim quantitative results. However, a general qualitative but also very significant observation can safely be made. The current density controls the strength, the amount and the porosity of the forming callus. Larger

Table 1 Results of mechanical testing

	Control bones	Stimulated bones	Percent of difference	Level of [illegible] of differ[illegible]*
Experiment 1				
Av cross-sectional area ($m^2 \times 10^{-6}$)	15 68	19 98	+27	0.11
Experiment 2				
Av maximum load to fracture (N)	158 50	142 79	−10	0.53
Av cross-sectional area ($m^2 \times 10^{-6}$)	29 95	33 54	+12	0.09
Av UTS (MPa)	5 56	4 45	−20	0.33
Experiment 3				
Av maximum load to fracture (N)	180 84	185 56	+ 3	0.53
Av cross sectional area ($m^2 \times 10^{-6}$)	37 2	34 3	− 8	0.34
Av UTS (MPa)	4 64	5 26	+13	0.5[illegible]

* *t* test for nonindependent samples.

current densities produce larger amounts of callus with higher porosity and poor strength

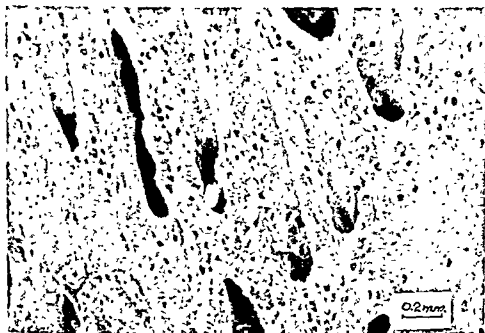
In order to get one step closer to the explanation of this phenomena, the morphology of the formed callus was examined The fractured ends of the bones were treated with Hydrazine (95 per cent) immersed in the bath of an ultrasonic cleaner This treatment removed the organic phase, cleaned the remaining debris and left only fully calcified trabeculae Control and stimulated callus were examined under the scanning electron microscope for the porosity and morphological formation of trabeculae.

Figures 2a and 2b show the typical formation of trabeculae in the callus of the control bones in all three experiments. Figure 2a is the transverse view and Figure 2b is the longitudinal view of the same callus. Both photomicrographs show a preferred orientation of trabeculae parallel to the long axis of the radius. Figure 3 shows a side view of a callus electrically stimulated for 2 weeks with the current of 123 μA cm² The arrangement of trabeculae is longitudinal away from the fractured surface, but right at the fractured site it changes to th[illegible] ansverse orientation corresponding to the direction of the current flow through the [illegible] Figure 4 is a side view of the call[illegible] fractured side stimulated with the cur[illegible] 41 μA/cm² Most of the callus [illegible] longitudinal orientation of trabeculae [illegible] exception of occasional protrusion[illegible] distinctly transverse trabecular one[illegible]

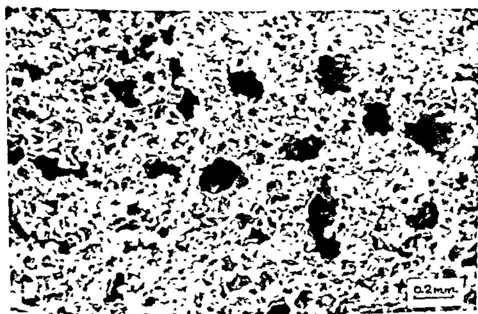
Conclusions

The fact that osteogenesis is stimulated [illegible] DC current has been documented befor[illegible] research may indicate that local stim[illegible] depends on the local current density [illegible] turn is dependent on the resistivity of [illegible] materials through which the current p[illegible] The dramatic illustration of this fact is [illegible] in Figure 4 It may be speculated that [illegible] lumps of callus on otherwise smooth [illegible] were the areas of higher current [illegible] resulting in a large amount of depos[illegible] bone The comparative results of the [illegible] sectional area of control and stimulated [illegible] in Experiments 1 and 2 show that [illegible] current produces much more call[illegible]

The growth of callus in the d[illegible] applied electric potential was obs[illegible] Yasuda (1974). The remarkable obser[illegible]



(a)



(b)

Figure 2. Transverse (a) and longitudinal (b) view of callus on the control side

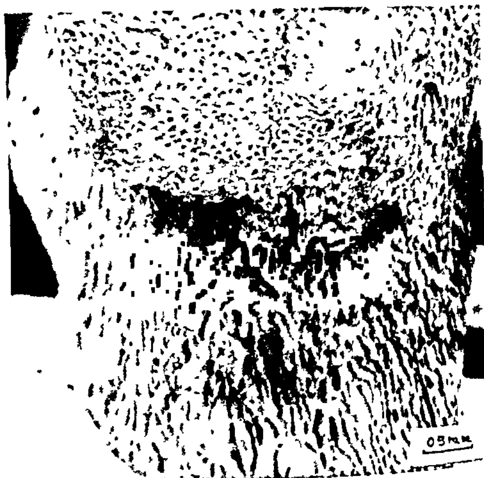


Figure 3 Side view of a callus electrically stimulated for 2 weeks with the 'current density' of 1.3.3

this investigation is the effect of current on the directionality of trabecular formation. It appears that the electrical potential predetermines the orientation of forming trabeculae in callus. In the normal healing process of bone there exists an electrical potential between the fractured ends which presumably controls the orientation of callus. Such a control results in the orientation of callus parallel to the long axis of the bone, which is observed in Figures 2a and 2b When a higher potential, resulting in a higher current density, is applied across the fracture site as in Experiments 1 and 2, the trabecular orientation on the fracture side, where the conductivity through the haematoma was high, is perpendicular to the long axis of the bone as though this were an orienting [illegible] on the natural currents between [illegible] ends. Figure 4 shows the effect of [illegible] potentials. The trabecular orientation [illegible] to change according to the localized [illegible] density The path of the high current [illegible] presumably found a low resistance [illegible] parts of the haematoma, formed [illegible] trabeculae oriented at right angles to the [illegible] of the callus. The localized higher [illegible] current still has not produced any [illegible] biological conditions except for the [illegible] the trabecular orientation. Thus [illegible] that a theoretical current density of [illegible] 40 $\mu A/cm^2$ is quite safe and the technique [illegible] have immediate clinical applications.



re 4 *Side view of a callus electrically stimulated for 3 weeks with the "current density" of 41 μA/cm²*

NOWLEDGEMENTS

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FERENCES

sett, C. A L., Pawluk, R. J & Becker, R O (1964) Effects of electric current in vivo *Nature Lond.)* 204, 652–654

sett, C. A. L, Pawluk, R. J & Pilla, A. A (1975) Acceleration of fracture repair by electromagnetic fields. *Ann. N Y Acad Sci* 238, 242–261

R. D & Murray, D G (1970) The electrical control system regulating fracture healing in amphibians. *Clin. Orthop* 73, 169–198.

Connolly, J F, Ortiz, Y, Price, R & Bayuzick, Y (1974) The effect of electrical stimulation on the biophysical properties of fracture healing *Ann. N Y Acad Sci* 238, 519–529

Digby, P S B (1966) Mechanism of calcification in mammalian bone *Nature (Lond)* 212, 1250–1252.

Digby, P S. B (1974) Potentials and calcification in mammalian teeth and artery An electrical basis. *Ann N Y Acad Sci.* 238, 202–213

Friedenberg, Z B, Andrews, E T, Smolenski, B I, Pearl, B W & Brighton, C. T (1970) Bone reaction to varying amounts of direct current. *Surg Gynec Obstet.* 131, 894–899

Haas, S L (1963) Stimulation of bone growth with an electric current. *J Bone Jt Surg* 45-A, 656

Iida, H, Ko, S, Miyashita, Y Sawada, S., Meada, M, Nagayama, H, Kawai, A. & Kitmura, S (1956) On electric callus produced by an alternating current. *J Kyoto Prefect Coll Med* 60, 561–564

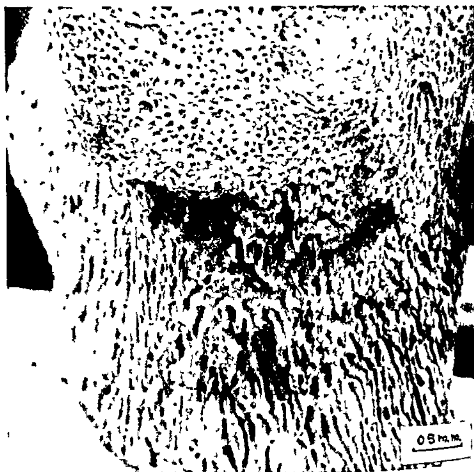


Figure 3 Side view of a callus electrically stimulated for 2 weeks with the "current density" of 123 µ

this investigation is the effect of current on the directionality of trabecular formation It appears that the electrical potential predetermines the orientation of forming trabeculae in callus In the normal healing process of bone there exists an electrical potential between the fractured ends which presumably controls the orientation of callus. Such a control results in the orientation of callus parallel to the long axis of the bone, which is observed in Figures 2a and 2b When a higher potential, resulting in a higher current density, is applied across the fracture site as in Experiments 1 and 2, the trabecular orientation on the fracture side, where the conductivity through the haematoma was high, is perpendicular to the long axis of the bone as though this were an overriding e on the natural currents between fract ends. Figure 4 shows the effect of potentials. The trabecular orientation to change according to the localized c density. The path of the high current, presumably found a low resistivity in parts of the haematoma, formed channe trabeculae oriented at right angles to the of the callus The localized higher de current still has not produced any biological conditions except for the the trabecular orientation Thus, it ap that a theoretical current density of 40 $\mu A/cm^2$ is quite safe and the technique have immediate clinical applications.

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ΗE HEALING OF CARTILAGE INJURIES UNDER THE IFLUENCE OF JOINT IMMOBILIZATION AND REPEATED YALURONIC ACID INJECTIONS

: Experimental Study

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In an experimental animal model the influence of intraarticularly injected high-molecular hyaluronic acid on the healing of superficial and deep lesions of the articular cartilage in freely mobile and immobilized joints was investigated In the right knee joint in 42 adult rabbits two intracartilaginous lesions were produced in one of the femoral condyles and an osteochondral lesion in the other In half of the animals the injured knee joint was [illegible]

graphically and the water content of the articular cartilage was determined. The intracartilaginous lesions remained unchanged in all knee joints. The wound margins of the osteochondral lesions showed better closure in the immobilized animals. As a rule the osteochondral lesion healed with fibrous connective tissue In a few joints, however, hyaline cartilage, with production of chondroitin sulphate, developed during healing of the osteochondral lesion. In the vicinity of the joint surface this tissue was transformed into fibrocartilage Immobilization of the joint invariably led to pannus formation. The hyaluronic acid injections appeared to have no effect either positive or negative, on the healing of intracartilaginous and osteochondral joint lesions. In mobile joints, however, these injections prevented a reduction of the water content of the articular cartilage, which was regarded as favourable

Key words articular cartilage, experimental injury immobilization hyaluronic acid

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ıs usually considered that osteochondral ınt lesions heal by invasion of connective ssue into the cartilage defect from the ıbchondral bone, with subsequent 'velopment into fibrocartilage (Bennet et al 332, Bennet & Bauer 1935, Campbell 1969, emperg & Hjertquist 1971, Puhl et al 1973) Sometimes metaplasia to hyaline cartilage has been observed (De Palma et al. 1966, Mitchell & Shepard 1976), although this cartilage gradually shows a greater resemblance to fibrocartilage (Lemperg et al 1971, Mitchell & Shepard 1976) It has also been found that immobilization of a joint in which an

experimental osteochondral lesion has been produced results in growth of richly vascular connective tissue—pannus—over the articular cartilage from the subchondral bone, causing cartilage destruction (Wigren & Olerud 1971, 1973, Wigren 1975) Intracartilaginous lesions produced experimentally have not given rise to osteoarthrosis and have not healed even after long periods of observation (Thompson 1974, 1975) It has been claimed that intraarticular injections of high-molecular hyaluronic acid promote the healing of cartilage lesions (Balazs 1974), and very good results in treatment of traumatic arthritis in race-horses has recently been reported (Åsheim & Lindblad 1976) In a previous study this substance, when injected in high doses, to some extent prevented articular cartilage degeneration caused by immobilization (Wigren et al 1975) The aim of the present investigation was to examine, in a larger material of adult rabbit knee joints, the effect of high molecular hyaluronic acid on the healing of superficial and deep experimental cartilage lesions treated with and without immobilization of the joint

MATERIAL AND METHODS

The study was performed on 42 adult rabbits of the Belgian Giant strain 2–3 years old and weighing 3 5–6 kg All rabbits were operated on under general barbiturate anaesthesia The right knee joint was exposed through a lateral parapatellar incision Using an oscillating saw a 200 µm wide osteochondral lesion was produced longitudinally

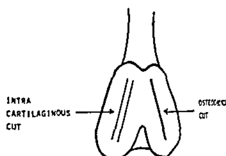


Figure 1 Schematic drawing of the location of experimental injuries on the femoral condyles.

on the medial femoral condyle and with a sc[illegible] two parallel intracartilaginous incisions were [illegible] [illegible] on the lateral femoral cond[illegible] [illegible] losed [illegible] [illegible] drain[illegible] [illegible] was used. Twenty-one of the rabbits w[illegible] immobilized with the knee joint in a [illegible] position in a plaster cast applied from the [illegible] the tip of the paw, while the other 21 rabbits w[illegible] allowed to move the knee joint freely A [illegible] was left in the plaster over the medial side of [illegible] knee joint for intraarticular injections. In [illegible] animals the left knee joint was left intact [illegible] control Once a week starting 3–6 days after [illegible] operation, 10 freely mobile and 10 immobiliz[illegible] knee joints were injected with 0 3 ml h[illegible] molecular hyaluronic acid (Sodium hyaluron[illegible] concentration 10 mg/ml, molecular weight 2 x [illegible] Pharmacia AB) while the other injured knee jo[illegible] were left untreated (Table 1) The treatment [illegible] continued for a total of 8 weeks, during which [illegible] the animals were allowed to move about fre[illegible] their cages. Within 1–2 weeks after the [illegible] injection i e 2–2 5 months after operation, Ind[illegible] Ink (Gunter-Wagner Pelikan ink in isotonic sal[illegible] solution) was infused under general anaesthe[illegible] through a cannula inserted in the abdominal [illegible]

Table 1 Macroscopic state of joint 2–2 5 months after osteochondral injury (The number of hyalur[illegible] acid injected joints is shown in the table)

	Mobile joint $n = 21$		Immobilized joint $n = 21$	
	Inj with hyaluronic acid $n = 10$	Not inj $n = 11$	Inj with hyaluronic acid $n = 10$	Not inj $n = 1$[illegible]
Vascular pannus over articular surface	1	3	8	1
Intraarticular adhesions	0	0	2	

ording to the method described by Olerud & *ith* (1963). The animal died during this infusion, ich was continued under positive pressure until)–700 ml of the solution had been given The e joint was then opened and carefully examined h respect to any signs of infection or injection ries. Specimens were taken from the medial and ral femoral condyles for histological, histomical and microangiographic examination. ing a scalpel 20–40 mg of cartilage was taken m the femoral part of the femoro-patellar joint analysis of its water content (Figure 2) cimens for light microscopy and histochemical mination were fixed in 10 per cent neutral malin, decalcified in a mixture of sodium citrate

M $MgCl_2$ (Stockwell & Scott 1965) for luation of the occurrence of chondroitin hate Parts of the condyles were sawn into mm thick slices and treated by the Spalteholz thod (1914) for microangiography For ermination of the water content of cartilage cimens, these were placed in weighed plastic es which were then reweighed, and freeze-dried a stable weight in an automatic freeze-dryer bold Heraeus GT 4) They were then weighed a balance (Mettler H 20 T) with a precision of mg

SULTS

acroscopic observations

the arthrotomy which completed the eriment 2–2 5 months after the operation, h the superficial and the deep cartilage ons were visible in all injured joints. No ns of intraarticular injection injuries or ction were seen In both immobilized and bile hyaluronic-acid-treated knee joints the ovial fluid was normal in appearance and ount In some of the mobile joints the tissue t had formed in the osteochondral lesion s strikingly light, i.e poorly vascularized scular pannus over the surface arising from osteochondral lesion or the margin of the icular surface, was seen in 4 of 21 mobile e joints and in 13 of 21 immobilized joints. is difference is statistically significant <0 01). Of the four mobile joints with wth of pannus, one had been treated with hyaluronic acid, while in the 13 immobilized joints with pannus 8 had received this treatment (Table 1) Intraarticular adhesions were observed in a further three immobilized injured knee joints. Two of these had been treated with hyaluronic acid. Vascular pannus and/or intraarticular adhesions were thus found macroscopically in 4 out of 21 mobile joints and in 16 out of 21 immobilized joints. This difference is statistically significant ($P < 0\ 001$)

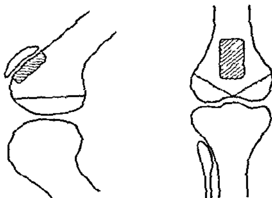


Figure 2 Schematic drawing of the sites on the femoral condyles from which the specimens were taken Dotted areas Specimens for histology, histochemistry and microangiography Hatched area Specimens for determination of water content

Histology and histochemistry

The intracartilaginous lesion At examination of serial-sectioned specimens stained with haematoxylin-eosin and van Gieson's stain, all intracartilaginous lesions were found to be still open, with no healing reaction (Figure 3). No difference between the groups was seen in this respect In no case did the scalpel incisions penetrate into the subchondral bone The hyaline cartilage immediately bordering on the incision had a normal histological appearance and showed no reaction to the injury (Figure 3)

The osteochondral lesion in mobile knee joints The wound margins had closed well in six



Figure 3 Open intracartilaginous lesion after 2½ months The absence of a healing reaction is illustrated Haematoxylin-eosin × 100



Figure 4 Fibrous connective tissue fills o deeper parts of this osteochondral lesion superficial part remains open The joint was and treated with hyaluronic acid. Haemat. eosin × 63

untreated joints and in four joints treated with hyaluronic acid (Table 2) This difference is not statistically significant. In the remaining injured joints the osteochondral wound was still more or less open to the cartilage surface

In most cases a vascularized fibrous connective tissue had formed in th teochondral wound cavity during the h process (Figure 4) In two joints each fro hyaluronic-acid-treated and the unt group the newly formed tissue rese hyaline cartilage, being avascular and h

Table 2 Status of the osteochondral wound 2–2 5 months after the lesion

	Mobile knee joints		Immobilized knee joints	
	Open wound	Closed wound	Open wound	Closed wo
Injected with hyaluronic acid	6	4	3	7
Not injected with hyaluronic acid	5	6	3	8

se fibrous components. In occasional s the basal part of the cartilage defect was l with bone tissue.

he blood vessels of the newly formed us tissue communicated with vessels in subchondral bone In the deeper part of the n the collagen fibres ran upwards from the chondral bone towards the surface of the ilage, while in the superficial regions the s were mostly parallel with the articular ace A moderate number of spindle-shaped cytes were seen in the fibrous tissue The rcellular substance did not stain with an Blue

n three lesions from either group, large oval round chondrocytes were observed, rounded by a territorial zone which stained ngly with Alcian Blue in the presence of M but not 0 9 M $MgCl_2$, indicating duction of chondroitin sulphate The ndrocytes formed hyaline cartilage, mainly he basal part of the lesion. In one case this hyaline cartilage contained cluster formations, and a proliferation of the tissue, which was undergoing transformation to fibrocartilage, formed a mushroom-like structure over the articular surface (Figure 5)

The amount of newly formed tissue varied considerably from knee joint to knee joint In this respect there appeared to be no difference between the untreated and the hyaluronic-acid-treated groups.

In five joints the newly formed fibrous tissue was most extensive at the level of the calcification zone of the cartilage In most joints the fibrous tissue decreased in amount in the superficial parts of the lesion and its surface lay at a lower level than the surrounding articular surface (Figure 4) In two cases from either group the newly formed tissue had grown beyond the level of the joint surface

The articular cartilage around the osteochondral lesion was apparently unaffected, apart from occasional cluster formations in



ure 5 From this osteochondral lesion an unusually large amount of fibrocartilaginous tissue has grown y the joint surface Some clusters are seen at the right hand margin of the proliferation The joint was bile and treated with hyaluronic acid van Gieson × 40

Figure 6. Most of the wound cavity is occupied by red bone marrow. A thin bone bridge has formed between the bone marrow and the fibrous pannus on the joint surface of this immobilized joint. van Gieson × 63.



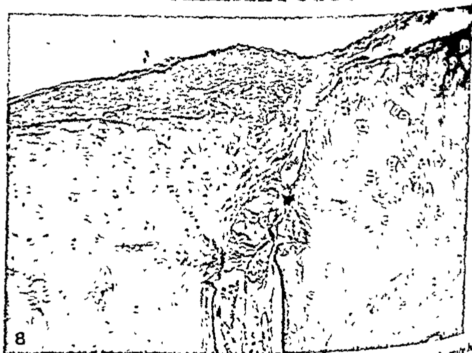


Figure 8. Only a small amount of reparative tissue is seen in this osteochondral wound [illegible] prominent fibrous pannus covers the joint surface of the immobilized knee joint. van Gieson × 40



Figure 7a. Microphotograph of the healing of an osteochondral lesion with hyaline-like cartilage in the bottom of the lesion. Towards the surface the tissue has a more fibrous appearance. Alcian Blue (0.4 M $MgCl_2$) × 40



Detail from the base of the wound in Figure 7a. Large chondrocytes are seen. Their matrix is ...ained with Alcian Blue at 0.4 M $MgCl_2$ but not at 0.9 M, indicating synthesis of chondroitin ...he joint was immobilized but not treated with hyaluronic acid. Alcian Blue (0.4 M $MgCl_2$)

one case On the whole, the articular cartilage was histologically unchanged Pannus growing over the articular surface was seen in only one of the joints.

The osteochondral lesion in immobilized knee joints No difference was found between hyaluronic-acid-treated and untreated knee joints with respect to closure of the wound margins (Table 2) The total number of closed lesions (15), on the other hand, was significantly greater than the number of open lesions (6) ($P < 0\ 05$) As in the mobile joints, the osteochondral lesion healed by formation of a vascularized fibrous tissue In one non-injected joint, however, the greater part of the newly formed tissue was avascular and its basal portion resembled hyaline tissue, while the superficial portion showed characteristics of fibrocartilage In seven joints the fibrous tissue was sparse and red subchondral bone marrow penetrated high up into the wound cavity (Figure 6) In 14 joints the fibrous tissue was separated from the red bone marrow by a bone bridge at the level of the calcification zone or surface layer of the cartilage (Figure 6) In these respects there was no difference between hyaluronic-acid treated and untreated

In the newly formed fibrous tissue a moderate number of spindle-shaped fibrocytes were seen, and superficially the collagen fibres ran parallel to the articular surface The intercellular substance did not stain with Alcian Blue

In one joint from either group a moderate number of large oval or round chondrocytes were observed in the basal part of the lesion Their matrices stained strongly with Alcian Blue at the lower of the two electrolyte concentrations used, indicating production of chondroitin sulphate (Figure 7a, b)

As in the mobile group the amount of newly formed tissue showed great individual variation and the two sub groups did not differ in this respect

It was difficult to evalute the level to which the newly formed tissue had reached as an outgrowth of connective tissue from the osteotomy gap, spreading over surface in the form of pannus (Figure 8), prominent in 10 of 11 untreated and in all of those injected acid

The articular cartilage close to exhibited no histological signs of teoarthrosis However, the articular as a whole showed areas of under the fibrous pannus and vessels into the cartilage bone as a reaction to the difference between immobilized non-immobilized injured knee, respect to the development of statistically significant ($P < 0\ 001$).

Microangiography

Mobile knee joints The subchondral the osteochondral lesion was richly larized, with a growth of occasional vessels into the cartilage up to the sub but not beyond it The newly the gap between the articular surface a tide-mark was very poorly vasculariz specimens from the three joints a protrusion of tissue with above the level of the articular surface the no vascular invasion into this tissue (Fig No growth of vascular pannus over the s was observed

Immobilized knee joints From vascularized tissue in the subchondral an abundance of blood vessels grew the lesion to the articular surface outwards over the surface of the cartilage joints (Figure 10) No difference was ob between hyaluronic-acid treated and untr joints Invasion of blood vessels into cartilage through the tide-mark was specimens from several joints.

Determination of the water content

Mobile knee joints Owing to mishaps specimens for water determination were only obtained from

9 Microangiogram showing the absence of blood vessels in the articular cartilage and in the ...ve tissue which is also seen in Figure 5 Spalteholz × 63

10 Microangiogram showing an abundant growth of blood vessels from the lesion and out over the ...rface Immobilized joint Spalteholz × 63

21 joints. The results are given in Table 3 In the group not treated with hyaluronic acid the water content of the articular cartilage was significantly lower in the injured joints ($P < 0\ 01$) than in the intact joints of the same animals In the hyaluronic-acid-treated group there was no significant decrease in this water content in the injured joint Thus there was a significant difference beween the water content of the articular cartilage in injured joints treated with repeated injections of hyaluronic acid and injured joints not injected with this substance ($P < 0\ 05$)

Immobilized knee joints Specimens were obtained from all joints The results are given in Table 4 Neither untreated nor hyaluronic-acid-treated knee joints showed any significant change in the water content of the articular cartilage

DISCUSSION

The treatment of intraarticular injuries is a constantly recurrent problem in orthopaedics. The question of whether or not osteochon[illegible] and intracartilaginous lesions heal [illegible] restoration of hyaline cartilage and o[illegible] degenerative changes of the articular car[illegible] develop, are of great importance. Immob[illegible]tion of an injured joint which is necessary, may give rise to irrevers[illegible] to the articular cartilage (Evans et al [illegible] Salter & Field 1960, Wigren & Olerud [illegible] 1973, Finsterbush & Friedman 1973 W[illegible] & Wik 1974) H[illegible] injected into an experimentally i[illegible] been reported to promote healing (R[illegible] Balazs 1971) It has been found that injectio[illegible] this substance at short intervals [illegible] act degenerative changes resulting [illegible] experimental immobilization (Wigren a[illegible] 1975) The osteochondral lesion produc[illegible] the present experiments healed [illegible] development of fibrous connective tiss[illegible] in some cases fibrocartilage in the same [illegible] has been reported by Campbell (1969) [illegible] others. The white scar tissue [illegible] macroscopically in the superficial cart[illegible] also been observed by Mitchell & [illegible] (1976) They found that after 8 week[illegible]

Table 3 The water content of the articular cartilage of adult rabbit femoral condyles 2 2 5 mo[illegible] experimental injury to the cartilage Freely mobile knee joint The influence of repeated [illegible] plantations of hyaluronic acid The articular cartilage from the intact knee joint of each rabbit [illegible] individual control

Animal no	% Water: Operation + hyal acid	% Water: Control knees	Water content in % of normal
13	70 0	70 1	99 9
17	67 9	68 4	99 3
18	68 2	67 5	101 0
19	69 2	69 9	99 0
23	62 7	68 0	92 2
25	69 4	67 7	102 5
30	64 0	58 6	109 2
			$n = 7$
			mean = 100 4
			S D = ± 5 1
			95 per cent confidence interval = 95 8–105 1

Animal no	% Water: Only operation	% Water: Control knees	Water content in % of [illegible]
2	63 5	68 1	[illegible]
3	67 3	67 1	[illegible]
4	58 8	67 6	[illegible]
7	69 5	69 3	[illegible]
8	56 3	68 8	[illegible]
9	60 8	64 6	[illegible]
11	68 4	68 5	[illegible]
12	57 4	67 1	[illegible]
28	63 6	64 6	[illegible]
29	61 6	66 3	[illegible]
			mea[illegible]
			SD [illegible]
		95 per cent confidence interval	[illegible]

... of the ... rabbit femoral condyles 2–2 5 months aft

% Water				% Water		
Operation + hyal. acid	Control knees	Water content in % of normal	Animal no	Only operation	Control knees	Water content in % of norma
72.3	71 5	101 0	1	66 7	67 1	99 3
63 7	68 7	92.7	3	63 5	68 4	92.9
66 1	66 2	99 8	4	68 3	68 3	99 9
69 0	68 3	101 0	6	68 5	68 4	100 2
72.4	69 0	105 0	9	62.2	71 5	87 0
72.2	71 1	101 5				
73 8	73 3	100 7	15	68 5	71 0	96 5
70 1	70 1	100 1	18	72 1	69 8	103 2
70 6	72.8	97 0	21	75 2	73 6	102 0
68 2	68 7	99 2	22	70 1	68 9	101 8
			24	69 0	70 6	97 8
			25	66 0	66 4	99 4
		$n = 10$				$n = 11$
		mean = 99 8				mean = 98 2
		S D = ±3 2				S D = ±4 7
r cent confidence interval = 97 5–102 1			95 per cent confidence interval = 95 0–101 3			

consisted of hyaline-like cartilage Such
; was seen in only a few cases in our The relative duration of the observation may be of significance for the type of found, but Lemperg & Hjertquist (1971) litchell & Shepard (1976) observed that e-like cartilage occurring early in the g process of a cartilage lesion underwent lary changes to dense fibrous tissue In resent study the cartilage defect closed frequently in the immobilized than in the e joints and in all immobilized joints the formed scar tissue was more richly larized and grew over the articular e as a pannus. This reaction is a quence of the immobilization (Evans et 60, Salter 1960, Wigren 1975) In the bilized joints an invasion into the ige by blood vessels was also observed, indication of cartilage injury (Mankin No histological signs of osteoarthrosis form of cluster formations or fibrillation observed in the articular cartilage The mental lesion did not seem to have ed osteoarthrosis, as has been claimed by Puhl & Dustmann (1973, 1976) Farkas et al (1976) have denied such a development, however It is widely agreed that normal mature articular cartilage does not show chondrocyte mitosis (Mankin 1963, 1974, Otte 1972) Our observation of an accumulation of chondroitin sulphate-producing chondrocytes in the basal regions of the osteochondral lesion corresponds with the findings of Mitchell & Shepard (1976) and might be explained by a dividing capacity of the chondrocytes which have been freed from the cartilage matrix during the production of the experimental lesion. Differentiation of immature cells to chondroitin sulphate-producing chondrocytes is another possibility – in this case induced by the trauma.

In a previous investigation (Wigren et al 1975) immobilization of a joint was found to cause a reduction of the water content of the articular cartilage This finding is in agreement with the changes observed by Akeson et al. (1974, 1975) in the connective tissue surrounding experimentally immobilized rabbit knee joints. In their study

21 joints. The results are given in Table 3 In the group not treated with hyaluronic acid the water content of the articular cartilage was significantly lower in the injured joints ($P < 0\ 01$) than in the intact joints of the same animals. In the hyaluronic-acid treated group there was *no significant* decrease in this water content in the injured joint Thus there was a significant difference beween the water content of the articular cartilage in injured joints treated with repeated injections of hyaluronic acid and injured joints not injected with this substance ($P < 0\ 05$)

Immobilized knee joints Specimens were obtained from all joints. The results are given in Table 4 Neither untreated nor hyaluronic-acid-treated knee joints showed any significant change in the water content of the articular cartilage

DISCUSSION

The treatment of intraarticular injuries is a constantly recurrent problem in orthopaedics. The question of whether or not [illegible] and intracartilaginous lesions heal [illegible] restoration of hyaline cartilage, degenerative changes of the develop, are of great importance tion of an injured joint, which is necessary, may give rise to [illegible] to the articular cartilage (Evans et al [illegible] Salter & Field 1960, Wigren & Olerud [illegible] 1973, Finsterbush & Friedman 19[illegible] & Wik 1974) High molecular hyaluronic [illegible] injected into an experimentally in[illegible] been reported to promote healing ([illegible] Balazs 1971) this substance at short intervals [illegible] act degenerative changes resulting [illegible] experimental immobilization (Wigren [illegible] 1975) The osteochondral lesion [illegible] the present experiments healed [illegible] development of fibrous connective [illegible] in some cases fibrocartilage has been reported by Campbell (1969[illegible] others. The white scar tissue [illegible] macroscopically in the superficial [illegible] also been observed by Mitchell & [illegible] (1976) They found that after 8 [illegible]

Table 3 The water content of the articular cartilage of adult rabbit femoral condyles 2 2.5 mon[illegible] experimental injury to the cartilage Freely mobile knee joint The influence of repeated intraarticular [illegible] plantations of hyaluronic acid The articular cartilage from the intact knee joint of each rabbit [illegible] individual control

	% Water				% Water		
Animal no	Operation + hyal. acid	Control knees	Water content in % of normal	Animal no	Only operation	Control knees	[illegible]
13	70 0	70 1	99 9	2	63 5	68 1	[illegible]
17	67 9	68 4	99 3	3	67 3	67 1	[illegible]
18	68 2	67 5	101 0	4	58 8	67 6	[illegible]
19	69 2	69 9	99 0	7	69 5	69 3	[illegible]
23	62.7	68 0	92.2	8	56 3	68 8	[illegible]
25	69 4	67 7	102.5	9	60 8	64 6	[illegible]
30	64 0	58 6	109 2	11	68.4	68 5	[illegible]
				12	57 4	67 1	[illegible]
				28	63 6	64 6	[illegible]
				29	61 6	66 3	[illegible]

$n = 7$
mean = 100 4
S D = ±5 1
95 per cent confidence interval = 95 8–105 1

95 per cent confidence interval [illegible]

l The water content of the articular cartilage of adult rabbit femoral condyles 2–2 5 months after rimental injury to the cartilage Immobilized knee joint The influence of repeated intraarticular tations of hyaluronic acid. The articular cartilage from the intact knee joint of each rabbit served as an individual control

% Water				% Water		
Operation + hyal. acid	Control knees	Water content in % of normal	Animal no.	Only operation	Control knees	Water content in % of normal
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72 4	69 0	105 0	9	62 2	71 5	87 0
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		S D = ±3 2				S D – ±4 7
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DISCUSSION

The treatment of intraarticular injuries is a constantly recurrent problem in orthopaedics. The question of whether or not osteoch[illegible] and intracartilaginous lesions [illegible] restoration of hyaline cartilage, and [illegible] degenerative changes of the articula[illegible] develop are of great importance. I[illegible] tion of an injured joint which [illegible] necessary, may give rise to irreversib[illegible] to the articular cartilage (Evans et [illegible] Salter & Field 1960 Wigren & Ol[illegible] 1973, Finsterbush & Friedman 19[illegible] & Wik 1974) High molecular [illegible] injected into an experimentally [illegible] been reported to promote healing [illegible] Balazs 1971) It has been found that in[illegible] this substance at short intervals [illegible] act degenerative changes result[illegible] experimental immobilization (Wig[illegible] 1975) The osteochondral lesion pr[illegible] the present experiments heal[illegible] development of fibrous connective t[illegible] in some cases fibrocartilage in the sa[illegible] has been reported by Campbell (196[illegible] others. The white scar tissue [illegible] macroscopically in the superficial car[illegible] also been observed by Mitchell & [illegible] (1976) They found that after 8 w[illegible]

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25	69 4	67 7	102.5
30	64 0	58 6	109 2

$n = 7$
mean – 100 4
S D – + 5 1
95 per cent confidence interval – 95 8 105 1

Animal no	% Water: Only operat on	% Water: Control knees	Water [illegible]
2	63 5	68 1	[illegible]
3	67 3	67 1	[illegible]
4	58 8	67 6	[illegible]
7	69 5	69 3	[illegible]
8	56 3	68 8	[illegible]
9	60 8	64 6	[illegible]
11	68 4	68.5	[illegible]
12	57 4	67 1	[illegible]
28	63 6	64 6	[illegible]
29	61 6	66.3	[illegible]

mean [illegible]
S.D. [illegible]
95 per cent confidence interval [illegible]

: the acid glycosaminoglycan (Muco-
lysaccharide) content of the matrix of ageing
rtilage *Ann. rheum. Dis* 24, 341–350
pson, R. (1974/1975) Experimental evidence
an injury threshold for articular cartilage. In
nference on articular cartilage, September
6, 1974 *Ann. rheum. Dis* 34, Suppl. 2,
)–142
n, A. & Olerud, S (1971) Reincorporation of
avascular articular surface bearing fragment.
a Soc. Med upsalien 76, 63–76.
ı, A. & Olerud, S (1973) Reincorporation of
avascular articular surface bearing bone
ment. *Upsal. J Med. Sci.*, Suppl. 14
ı, A. & Wik, O (1974) The influence of
uronic acid on immobilized knees. *Upsal. J
' Sci.*, Suppl. 16.
A., Wik, O & Falk, J (1975) Repeated in-
ticular implantation of hyaluronic acid. An
rimental study in normal and immobilized
rabbit knee joints. *Upsal. J Med. Sci.*,
l. 17
A. (1975) Experimental studies in
bilized knee joints. *Acta Univ Upsal.*
s No 231
A., Wik, O & Falk, J (1976) Intra-
lar injection of high molecular hyaluronic
An experimental study on normal adult
knee joints. *Acta orthop scand* 47,
35

ıopaedic Surgery, University Hospital,

a reduced water content was associated with a decreased content of hyaluronic acid, a decreased amount of soluble collagen and a decreased content of hexosamine These changes were also accompanied by impairment of biomechanical properties (Akeson et al 1975) In the present experiments injection of high-molecular hyaluronic acid counteracted a reduction of the water content of the articular cartilage in the experimentally injured, but mobile joint How this effect is mediated is not clear (Wigren et al. 1975) The synovial membrane plays some role (Wigren et al 1976) Adsorption of the greatly hydrophilic hyaluronic acid molecule to the surface of the articular cartilage may be another mechanism *In the immobilized joints the water content of* the articular cartilage was not affected This may have been due to technical difficulties in the sampling (Sokoloff & Hough 1975) or to concealment of a reduction in water content by richly vascular pannus over the cartilage surface, which might have accompanied and influenced the sample

The intracartilaginous lesion had not healed ' showed no reaction whatsoever after 2 5 months. This finding is in agreement with reports by Thompson (1974, 1975) No reaction of the subchondral bone beneath the lesion, as was described by Lemperg et al (1971), was seen The articular cartilage around the lesion was completely unaffected, and showed no degenerative changes The need for serial sectioning of specimens in evaluating intracartilaginous lesions must be emphasized, as apparent closure of the wound margins may give the impression that the lesion has healed Injections of high-molecular hyaluronic acid appeared to have no effect on the intracartilaginous lesion

REFERENCES

Åsheim, Å. & Lindblad, G (1976) Intraarticular treatment of arthritis in race-horses with sodium hyaluronate *Acta vet scand* **17**, 379–394

Akeson, W H, Woo, L Y, Amiel, D & Matthews J V (1974) Biomechanical and biochemical changes in the periarticular connective tissue during contracture development i immobilized rabbit knee *Connect. Tiss.* 315–323

Akeson, W H, Woo S L-Y, Am Matthews, J V & Rutherford L. Lubrication defect of immobilized con tissue matrices. *Ann rheum Dis* 34, S. 100–103

Bal [illegible]

B Lippincott Co, Philadelphia.

Bennet, G A., Bauer, W & Maddoch, S. (1 study in the repair of articular cartilage. *J Path* **8**, 499–525

[illegible]

remobilization of rat knee joints. *J* *Surg* **42-A**, 737–758

Farkas, T A, Biro, T & Bihari Varga, M (Early changes in the composition of articular cartilage following experim produced intra articular fractures. *Acta scand* **46**, 716–726

Finsterbush, A & Friedman, B (19 changes in immobilized rabbits knee light and electron microscopic study *Orthop* **92**, 305–319

Lemperg, R & Hjertquist, S O (Histological, autoradiographic and chemical studies of spontaneously healing teochondral articular defects in adult *Calcif Tiss Res* **8**, 54–72

Lemperg, R, Boquist, L & Rosenquist, J (Intracartilaginous defects in adult *Virchows Arch path Anat* 354, 1 16

Mankin, H J (1963) Localization of thymidine in articular cartilage of rabbit Mature articular cartilage *J Bone Jt Surg* A, 529–540

Mankin, H J (1974) The reaction of cartilage to injury and osteoarthritis. *New E J Med* **291**, 1284–1292 and 1335–1340

Mitchell, N & Shepard, N (1976) The result of adult rabbit articular cartilage by perforations through the subchondral bo *Bone Jt Surg* **58 A**, 230–233

Olerud S & Hulth A (1963) Morfologis av callusbildningen *Acta Soc Med.* **67**, 307–311

Otte, P (1972) Die Verpflanzung Gelenkknorpeln Die Biologie Gelenkknorpels im Hinblick Transplantation *Z Orthop* 110, 677–

ılma A F, McKeever, C. D & Subın, D K. 966) Process of repair of artıcular cartılage :monstrated by hıstology and autoradıography ıth trıtıated thymıdıne *Clın Orthop* 48, 29–242.

[illegible]

, W & Dustmann, H O (1976) ltersabhangıge Heılungsmöglıchkeıten von norpelwunden. *Z Orthop* 114, 749–764

ll, N W & Balazs, E A. (1971) Effect of ın-aartıcular ınjectıon of hyaluronıc acıd on the ınıcal symptoms of osteoarthrıtıs and on anulatıon tıssue formatıon. *Clın. Orthop* 80, 5–32.

r, R. B & Fıeld, P (1960) The effects of ontınuous compressıon on lıvıng artıcular rtılage. An experımental ınvestıgatıon *J one Jt Surg* 42-A, 31–49

loff, L & Hough, A J (1975) Tıssue mplıng as a potentıal source of error ın xperımental studıes of cartılage *Connect Tıs* es 3, 27–31

teholz, K W (1914) *Über das urchsıchtmachen von menschlıchen und erıschen Preparaten* Zweıte Auflage S ırzel, Leıpzıg

kwell, R. A. & Scott, J E (1965) Observatıons on the acıd glycosamınoglycan (Mucopolysaccharıde) content of the matrıx of ageıng cartılage *Ann. rheum Dıs* 24, 341–350

Thompson, R (1974/1975) Experımental evıdence for an ınjury threshold for artıcular cartılage. In: *Conference on artıcular cartılage*, September 2–6, 1974 *Ann rheum. Dıs* 34, Suppl. 2, 140–142.

Wıgren, A & Olerud, S (1971) Reıncorporatıon of an avascular artıcular surface bearıng fragment. *Acta Soc Med upsalıen* 76, 63–76

Wıgren, A & Olerud, S (1973) Reıncorporatıon of an avascular artıcular surface bearıng bone fragment. *Upsal J Med Scı*, Suppl. 14

Wıgren, A & Wık, O (1974) The ınfluence of hyaluronıc acıd on ımmobılızed knees. *Upsal J Med Scı*, Suppl. 16.

Wıgren, A., Wık, O & Falk, J (1975) Repeated ıntraartıcular ımplantatıon of hyaluronıc acıd. An experımental study ın normal and ımmobılızed adult rabbıt knee joınts *Upsal. J Med Scı.*, Suppl 17

Wıgren, A. (1975) Experımental studıes ın ımmobılızed knee joınts. *Acta Unıv Upsal.* Thesıs No 231

Wıgren, A, Wık, O & Falk, J (1976) Intraartıcular ınjectıon of hıgh-molecular hyaluronıc acıd. An experımental study on normal adult rabbıt knee joınts. *Acta orthop scand* 47, 480–485

espondence to Anders Wıgren, M D, Department of Orthopaedıc Surgery, Unıversıty Hospıtal, 14 Uppsala, Sweden.

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METASTATIC OSTEOMYELITIS FOLLOWING BCG VACCINATION

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An 8-year-old girl, who had been vaccinated with BCG without suf regional reactions, developed osteomyelitis in the left calcaneus 7 later The process healed after surgical treatment and chemotheraj year Culture from the bone abscess gave growth of mycobacteri could not be distinguished from BCG

Key words metastatic osteomyelitis, BCG vaccination

Accepted 14 xii 77

Metastatic osteomyelitis after BCG vaccination is a complication which has been reported only infrequently Foucard & " ' (1971) reported 13 cases, 9 of h were from Scandinavia However, has been much interest in this com during recent years, particularly in Sweden and Finland, where it is taken into consideration in the discussions on vaccination policy Only two such cases have been diagnosed previously in Denmark (Bang et al 1960, Mørkbak 1954) and the third is reported in this work

CASE REPORT

An 8 year-old girl previously healthy, was referred as an outpatient to the Orthopaedic Surgical Department on October 24, 1969, because of progressive pain in the left heel on weight-bearing and swelling around the lateral malleolus. Four months prior to the commencement of symptoms, the girl had been vaccinated with BCG at the Chest Clinic, without any known reactions.

Physical examination revealed a pronounced limp in the left leg, marked swelling behind the lateral malleolus, and slight tenderness calcaneus The sedimentation rate was 38-

X ray examination of the left foot showe halisteresis and tomography a few showed a destructive process in the extending to the surface of the joint. An was performed, and 3 ml pus and a fragment were evacuated from an tuber calcanei

Microscopy of the pus (Z showed no acid and alcohol fast rods, bu gave growth of mycobacteria which could distinguished from BCG on the basis morphology, biochemical tests and determination on guinea pig (Engbæk et al. I

Treatment was started with (50 mg × 3) and neothebamin (4 mg × 3) after the operation The bacteria isolated highly sensitive to SM PAS INH Rifa and Ethambutol

The patient was reoperated 4 months because of continued secretion and f cavity filled with purulent bone tissue granulation tissue was found occupying almo whole calcaneus. Microscopy revealed tuber granulation tissue with necrosis.

Ziehl-Neelsen staining showed no acid alcohol fast rods and PAS staining showed no Culture gave no growth of acid and alcohol rods

During the anti tuberculous treatment streptomycin (total 16 5 g) and ery



: 1 and 2 Tomography showing destructive process in the tuber calcanei extending to the surface of
:(7 11 1969)



3 and 4 X-ray performed about 13 months later (same case as in Figures 1 and 2) showing
of the process in the left calcaneus (15 12 70)

Acta orthop scand 49, 138 142 1978

LARSEN'S SYNDROME

HELGE RØNNINGEN & INGJALD BJERKREIM

Sophies Minde Orthopaedic Hospital University of Oslo Oslo Norway

A girl with the characteristic abnormalities of Larsen s [illegible] presented. A soft flabby consistence of the cartilaginous skeleton of the [illegible] and trachea was thought to be the cause of attacks of respiratory [illegible] which suddenly caused her death at the age of 9 months. [illegible] revealed a considerably reduced number of elastic fibres in the larynx, [illegible] and bronchi Closed reduction of the knee dislocation by skin traction [illegible] to be successful

Key words congenital malformations knee dislocat on

Accepted 17 x 77

The first description of the disorder later known as Larsen's syndrome was given by Kaijser (1935) He reported a case with congenital malformations including dislocation and facial deformities. There [illegible]) also a *family history of congenital* [illegible]formities of the musculo-skeletal system Larsen et al (1950) reported six unrelated patients with multiple joint dislocations depressed nasal bridge and wide-spaced eyes. The joints most often affected were the knees, elbows and hips. Abnormalities of the foot hand and spine, and cleft palate were also found

Since this publication, some reports have appeared describing cases consistent with Larsen s *syndrome* (Curtis & *Fisher 1970* Steel & Kohl 1972 Micheli et al 1976 Oki et al 1975) New findings have also been added to the clinical and pathologic-anatomic entity Latta et al. (1971) reported malformation of the larynx giving respiratory distress Most authors have found a familial occurrence of the syndrome and *Habermann et al (1976)* reported four cases of Larsen s syndrome in three generations of one family and suggested a dominant mode of inheritance

The purpose of the *present paper* [illegible] *report* a case of Larsen s syndrome [illegible] the patient suffered from attacks of [illegible] failure One such attack resulted in her [illegible] death at 9 months of age In this patient [illegible] *reduction* of the knee dislocation [illegible] attempted using skin traction.

CASE REPORT

The patient was a girl, *3 months of age when* [illegible] *for the first time* [illegible]
Hosp tal
right knee
old woman
older sister [illegible] had an unusual shape of the [illegible] with depressed nasal bridge and hyper[illegible] The father also had syndactylism of toes of [illegible] feet, and he *had* had a plastic operation for [illegible] flattened nose The sister had short first metat[illegible] bones.

Shortly after birth it was not ced that [illegible] had a dislocation of her right knee [illegible] characteristic *appearance* with depressed [illegible] bridge and hypertelorism (Figure 1). [illegible] palate was high arched Calcaneo-valgus def[illegible] and short first metatarsal bones of both [illegible] found (Figure 2). Examination of the hips [illegible] a positive *dislocat* on test on the left side. [illegible]



re 1 Depressed nasal bridge and ocular rtelorism in a 6 month-old girl with Larsen's rome



Figure 2 Short first metatarsal bone in Larsen's syndrome

a pectus excavatum deformity Closed tion of the dislocated knee was attempted but . The hip dislocation was treated by a Frejka y and the foot deformity by corrective casts. few days after birth, attacks of respiratory ss with cyanosis supervened. The attacks apt to occur during meals, and the patient had fed through a stomach tube for some weeks. t laryngoscopy showed a soft, easily ing epiglottis and hypoplasia of the oid cartilage During the first 6 months of attacks became more infrequent, and when aedic treatment of the knee dislocation l, the respiratory failure was considered

iographs of the entire skeleton revealed an r dislocation of the right tibia on the femur, t dysplasia of the left acetabulum, an extra tion centre of os calcis and a short first rsal bone of both feet. A general muscular ny was found Laboratory findings g chemical studies of serum and urine and ardiograms were normal as was muscle

tment was started with skin traction, the knee in semi flexion and countertraction applied on the distal thigh. After 3 weeks of traction radiographs showed that the dislocation was almost reduced to a normal position (Figure 3) However, sudden death supervened at this time due to an attack of respiratory failure

Necropsy showed a soft, flabby consistence of the epiglottis and arytenoid cartilage Trachea and larynx were partially collapsed No signs of aspirated food or cardiac malformation were found. Microscopy revealed a markedly reduced number of elastic fibres in the larynx, trachea and bronchi Signs of an interstitial pneumonia were also found

The right patella was connected to the femoral condyles by fibrous tissue occupying the entire suprapatellar pouch. Splitting of the infrapatellar tendon and the anterior part of the capsule led to reduction in the flexed position.

DISCUSSION

A girl having physical findings consistent with Larsen's syndrome is presented. Her father



Figure 3 Anterior dislocation of the tibia (a) The knee almost reduced in skin traction (b)

and sister also had some deformities characteristic of this syndrome, and her mother had had two abortions. The family history could point to a dominant mode of inheritance with a wide variety in the penetrance of the disorder Our case had a distinct maldevelopment of the cartilaginous skeleton of the larynx and trachea, verified at autopsy Histological examinations revealed reduction of elastic fibres in these structures. This finding has not previously been reported in Larsen's syndrome

At present Larsen's syndrome is a rather complex and not well defined entity In Table 1 all abnormalities ever described in cases supposed to have this disorder are listed Our patient has added two abnormalities to the list, pectus excavatum and short fi… metatarsal bones

Closed reduction of the knee was attemp… at the local hospital shortly after birth b… failed At our hospital operative treatment w… planned for when the respiratory proble… were overcome As a preoperative proced… skin traction was applied. Reduction b… almost succeeded when the patient sudd… died Oki et al (1976) also reported succ… closed reduction of knee dislocation … skeletal traction Most authors, howe… advocate operative treatment and early … surgical procedures (Larsen et al. 1950, Oet… & Fisher 1970)

ible 1 Abnormalities described in patients with Larsen's syndrome (Taken from the reviewed literature) The most typical deformities are in italics

Abnormalities affecting the musculoskeletal system	
eral	*Muscular hypotonia*
ut	*Prominent forehead with depressed nasal bridge and widespaced eyes* Maldeveloped maxilla. Supernumerary incisors.
ebral mn and age	Spina bifida Abnormal segmentation. Fusion between atlas and skull. Flattened hypoplastic vertebrae Pectus carinatum/excavatum.
er emity	[illegible] centres. Short metacarpals, sometimes with pseudoepiphyses on the bases of the 2nd and 3rd metacarpals.
ver emity	*Dislocated hip joints Anterior dislocation of the knees* *Extra ossification centre of the calcaneus* Pes equinovarus/valgus. Short 1st metatarsals. Bifid cuboid bone Subluxation in Lisfrance's joint
Other manifestations	
ital elopment	Retarded in a few patients.
tral nervous em	Gliosis in the cervical medulla (described in a patient with abnormality in the cervical column)
piratory t, oral ty	*Maldeveloped laryngeal cartilage and tracheal rings* *Cleft* palate/uvula.
ito-urinary t	Undescended testicles

Micheli et al. (1975) reported three cases of rsen's syndrome with bone abnormalities of cervical spine In one of these cases spinal tability with damage to the spinal cord was isidered to be the factor causing a fatal come In our case no spinal abnormalities re found. The attacks of respiratory failure st probably were caused by the maldevelopnt of the larynx and trachea. In the medical · of patients with Larsen's syndrome the piratory problems must be given special ention.

REFERENCES

Curtis, B H & Fisher, R. L. (1970) Heritable congenital tibiofemoral subluxation. Clinical features and surgical treatment. *J Bone Jt Surg* 52–A, 1104–1114

Habermann, E. T, Sterling A. & Dennis, R I (1976) Larsen's syndrome A heritable disorder *J Bone Jt Surg* 58–A, 558–561

Kaijser, R (1935) Über kongenitale Kniegelenksluxationen. *Acta orthop scand* 6, 1–20

Larsen, L. J, Schottstaedt, E R & Bost, F C (1950) Multiple congenital dislocations

associated with characteristic facial abnormality *J Pediat* 37, 574–581

Latta, R J, Graham, C. B, Aase, J, Scham, S M & Smith, D W (1971) Larsen's syndrome A skeletal dysplasia with multiple joint dislocations and unusual facies. *J Pediat* 78, 291–298

Micheli, L J, Hall, J E & Watts, H G (1976) Spinal instability in Larsen's syndrome *J Bone Jt Surg* 58–A, 562–565

Oki, T, Terashima, Y, Murachi, S. & [illegible] (1975) Clinical features and treatment of dislocations in Larsen's syndrome. [illegible] *Orthop* 119, 206–210

Steel, H H & Kohl, E. J (1972) [illegible] congenital dislocations associated with [illegible] skeletal anomalies (Larsen's syndrome) in [illegible] siblings. *J Bone Jt Surg* 54–A 75 82

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NE MINERAL CONTENT IN WOMEN WITH LLES' FRACTURE·

FECT OF CALCIUM SUPPLEMENTATION

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The effect of dietary calcium supplementation on bone mineral content was *studied* in *40* postmenopausal women with Colles fracture The participants were divided into two groups which were given either placebo or 1 g of calcium per day The bone mineral content of the femur was determined before and after 1 year of medication

Women with Colles' fracture were found to have the same mineral content in the femur as age-matched controls without fractures. Calcium supplementation had no significant effect on the bone mineral content.

Key words osteoporosis fractura radii dietary calcium bone mineral absorptiometry

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y women have a high incidence of ' fracture (Alffram & Bauer 1962) This e at least partly explained by a reduced unical strength of the skeleton due to the lated loss of bone tissue and mineral in women normally begins in the decade (Garn et al 1969) The etiology loss of bone is not known although s factors, such as dietary calcium ncy, have been proposed (Nordin 1960)

aim of the present investigation was d (i) to collect data on the bone l content of women with Colles' e and, (ii) to study the effect of dietary n on the bone mineral content of these s.

RIAL AND METHODS

postmenopausal women with previous of the distal forearm volunteered for the All had sustained fractures approximately 3 years previously Twelve patients had had repeated unilateral or bilateral Colles' fractures.

The mineral content of the patients with previous fractures, measured as described below was compared with that of age-matched controls without fractures. The controls comprised 15 female staff members and 12 women drawn at random from the Stockholm population. The latter had participated in a study of the bone mineral content in a normal population (Dalén & Lamke 1974). The age was 60 ± 3 (mean ± s.d.) years in the fracture as well as the control groups.

In order to study the effect of calcium supplementation, the patients with Colles fracture were divided randomly into two groups which were given either placebo or calcium tablets (Calcium Sandoz® 0 5 g one tablet twice daily) Mineral measurements were made before and after 1 year of treatment Four patients who discontinued the medication (1 calcium and 3 placebo) were excluded from the study The actual daily supplement on an average was 0 8 g calcium, estimated on the bas s of information received from the patients and from our records.

The bone mineral content was determined by X-ray spectrophotometry (Jacobson 1964 Gustafsson et al. 1974). In this method the

skeletal part under examination is positioned by fluoroscopy and automatically scanned with a beam of two energy levels from an X-ray tube The attenuation of the beam is recorded as a profile giving the mineral content expressed in mg/mm The femoral neck and shaft were chosen for measurement of the mineral content (cf, Dalén & Jacobson 1974) Earlier investigators have used the non-injured forearm as the measuring site This was not done in the present study, since several patients had had bilateral Colles' fractures The statistical evaluations were made according to Student's *t*-test

RESULTS

As seen in Table 1, there was no significant difference in the mineral content of women with and without Colles' fracture ($P > 0\ 05$)

Table 2 shows the percentage change in mineral content in the fracture group during 1 year The patients given placebo lost on an average 1 per cent which is in accordance with the normal mineral loss in this age group (Dalén & Jacobson 1974) The patients given calcium supplement increased their mineral content by 3 per cent on an average This difference between the placebo and calcium groups was, however, not s gnific ($P > 0\ 05$)

DISCUSSION

In the present study women with C fracture were found to have the same content in the femur as the contro T related loss of mineral in the femur is same magnitude as in other parts of skeleton (Dalén & Jacobson 1974) and mineral content of the forearm correlates that of the whole skeleton (Chestnut III e 1973) Thus, the lack of difference femoral bone mineral content betw women with fractures and controls probably representative of the whole skele

Westlin (1974) found that women Colles' fracture were slightly leaner and ha somewhat lower mineral content in uninjured forearm than controls. The rate loss of bone mineral with age was howe not increased The author's interpretation these findings was that women with Col fracture have a constitutionally low mine

able 1 Bone mineral content in women with lower forearm fractures (n = 40) and controls w fractures (n = 27) The age was 60 ± 3 (mean ± s d) years in both groups

	Control group Mean ± s d		Fracture group Mean ± s d		D fference		
	(mg/mm)		(mg/mm)		%	*t*	*P*
Femur, neck	256	42	258	46	+1	0 2	>0 05
Femur, shaft	430	69	422	58	−2	0 5	>0 05

Table 2 Percentage change in bone mineral content during a period of 1 year in women with Co fracture The patients were divided randomly into two groups which were given either calcium s ment (n − 19) or placebo (n = 17) The age was 60 ± 3 (mean ± s d) years in both groups

	Placebo		Calcium		Difference		
	Mean + s d		Mean ± s d		%	*t*	*P*
Femur, neck	−1 6	7 8	+2 9	11 3	+4 5	1 4	>0 05
Femur, shaft	−0 4	5 8	+3 7	7 7	+4 2	1 8	>0 05
Femur, mean of both sites	−1 1	5 6	+3 3	7 8	+4 4	1 9	>0 05

ent in the forearm rather than accelerated : mineral loss.

orseman (1976) also determined the :ral content of the distal forearm, but d no clear difference between a group fractures and a control group

he results of these studies indicate that ien with Colles' fracture differ only itly from controls and that the majority of ents with Colles' fracture have a mineral ent within the normal range for their age nen in this age group have a lower bone eral content than premenopausal women high incidence of Colles' fracture in menopausal women may therefore be lained by the age related bone loss Within high risk group factors other than the bone eral content probably determine which nen will develop Colles' fracture One such or may be the degree or frequency of ima

n the prospective part of the present dy, patients treated with calcium increased ir mineral content, although not nificantly Thus, no definite conclusions be drawn as to the beneficial effect from ium supplementation Certainly, calcium a necessary component of the diet for the intenance of a normal skeleton, but the ct requirements of calcium in various age ups are not known Elderly people show a dency to decrease their calcium intake urxthal & Vose 1969) sometimes because lactase deficiency (Birge et al 1967), and ir calcium intake is low compared to losses in the gut, kidneys and skin (Lutwak 69)

Dietary calcium supplementation has been nd to increase the bone mineral content in ients with periodontal disease (Lutwak & ulston 1973) and in normal elderly people banese et al. 1973), but not in patients h spinal osteoporosis (Shapiro et al 1975) this connection it is of special interest that pulations with high calcium intake are not tected against bone loss (Garn et al 1969) is indicates that calcium deficiency is not only factor involved in the etiology of age ated bone loss.

REFERENCES

Albanese, A A, Edelson, A H, Woodhull, M L, Lorenze, Jr, E J, Wein, E H & Orto, L A (1973) Effect of a calcium supplement on serum cholesterol, calcium, phosphorus and bone density of "normal, healthy" elderly females. *Nutr Reports Int* **8**, 119–130

Alffram, P-A & Bauer, G C H (1962) Epidemiology of fractures of the forearm A biomechanical investigation of bone strength *J Bone Jt Surg* 44-A, 105–114

Birge, Jr, S J, Keutmann, H T, Cautrecasas, P & Whedon, G D (1967) Osteoporosis, intestinal lactase deficiency and low dietary calcium intake *New Engl J Med* **276**, 445–448

Chestnut, C H, III, Manzke, E, Baylink, D & Nelp, W B (1973) Correlation of total-body calcium (bone mass) and regional bone mass in osteoporosis. *International conference on bone mineral measurement, Chicago* U S Department of Health, Education and Welfare No 75–683, 34–38

Dalén N & Jacobson, B (1974) Bone mineral assay Choice of measuring sites. *Invest Radiol* 9, 174–185

Dalén, N & Lamke, B (1974) Grading of osteoporosis by skeletal roentgenology and bone scanning *Acta radiol (Stockh)* **15**, 177–186

Garn, S M, Rohmann C G, Wagner, B, Davila G H & Ascoli, W (1969) Population similarities in the onset and rate of adult endosteal bone loss. *Clin Orthop* **65**, 51–60

Gustafsson, L, Jacobson, B & Kusoffsky, L (1974) X-ray spectrophotometry for bone mineral determinations. *Med biol Engng* **12**, 113–118

Horseman, A (1976) In *Calcium, phosphate and magnesium metabolism.* Ed Nordin B E C Churchill Livingstone

Hurxthal, L M & Vose, G P (1969) The relationship of dietary calcium intake to radiographic bone density in normal and osteoporotic persons. *Calcif Tiss Res* **4**, 245–256.

Jacobson, B (1964) X-ray spectrophotometry in vivo *Amer J Roentgenol* 91, 202–210

Lutwak, L. (1969) Nutritional aspects of osteoporosis. *J Amer Geriat Soc.* **17**, 115–119

Lutwak, L & Coulston, A. (1973) Dietary calcium and the jaw bone *International conference on bone mineral measurement* U S Department of Health, Education and Welfare No. 75–683, 285–292.

Nordin, B E. C. (1960) Osteomalacia, osteoporosis and calcium deficiency *Clin Orthop* **17**, 235–258

Shapiro, J R, Moore, W T, Jorgensen H, Reid J, Epps C. H & Whedon, D (1975) Osteoporosis. Evaluation of diagnosis and therapy *Arch intern Med.* 135, 563–567

Westlin N E (1974) Bone mineral in Colles fracture Thesis University of Lund, Sweden

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ECURRING DIGITAL FIBROMAS OF INFANCY

Case Report

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A case of recurring digital fibromas of infancy, with bilateral absence of the second metatarsal and deformed third metatarsal, is reported.

Key words digital fibroma, recurring, infancy

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urring digital fibromas of infancy is a rare dition, the clinical features and behaviour which have been discussed in detail by e (1965) The published reports of the urrence of this disease are scanty (Grunnet l. 1973, Bloem et al 1974) We report one h case, believing it to be the first reported n India

SE REPORT

11 month-old female infant was brought to the hopaedic Clinic of JIPMER Hospital Pondicrry, with a history of progressive swellings the distal parts of the fingers, one on the and four on the right hand associated with teral deformed second toes. One week after h a small swelling was noticed on the left ring er Subsequently similar swellings appeared after another on other fingers. The swellings eased rapidly in size The extent and distribu- of the tumours are shown in Figure 1 The st prominent growths were on the dorsolateral ion of the left ring finger and on the right ring, ldle and right index fingers. The tumours olved the terminal phalanges sparing the nails. ere was a small growth on the lateral side of right little finger The tumours were firm and nless. The overlying skin was red and shining e tumours were fixed to the skin and underly- tissues except for the small one on the little finger which adhered to the skin only There were flexion contractures of the right ring and four left fingers Bilateral syndactyly and flexion contracture of the second toe were also present (Figure 2) The lower lip had an abundance of vermillion

On X-rays the four radial metacarpals on the left side were seen to be short and deformed (Figure 3). There was bilateral absence of the second and hypoplasia of the third metatarsal (Figure 4)

Arteriography showed the avascular nature of the tumours (Figure 5) This was confirmed during excision of one of the tumours, no bleeding occurring during surgery The specimen removed was a nonencapsulated greyish white fibrous mass. Histopathological examination showed that the dermis was replaced by interlacing bands of fibrous connective tissue with an abundance of collagen similar to dermato-fibromas with no sign of malignancy A section of deformed bone showed a normal histopathological appearance The tumour tissue did not yield any viral agent in monkey kidney, vero and He-la cell lines.

DISCUSSION

According to Bloem et al. (1974) recurring digital fibromas of infancy are common in females. They arise from the fingers, and are often multiple in distribution. They start as small nodules which may increase to an



Figure 1 Fibromas on both hand



Figure 2 Flexion contracture syndactyly of the second toe

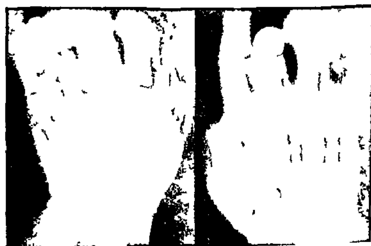


Figure 3 X rays showing and deformed metacarpals of the left hand.



Figure 4 X ray showing bilateral absence of the second and hypoplasia of the third metatarsals



ure 5 Arteriogram showing the avascular ture of the tumours

ormous size, affecting mainly the rsolateral aspect of the distal parts of joining fingers. The covering skin may come reddish in colour and fixed to the mour The swellings are painless and often here to the deeper tissues sparing the nes. The cut section is avascular and eyish white in colour Microscopically, the dermis is replaced by interlacing bands of fibrous tissue with an abundance of collagen The site of origin, tendency to recurrence and the presence of cystoplasmic inclusion bodies (Reye 1965, Ahlqvist et al 1967, Burry et al. 1970, Battifora & Hines 1971) are the main features by which these tumours are differentiated from other forms of fibromatosis. Bloem et al (1974) also described the presence of flexion contracture and deformed metacarpals of the affected fingers and an abundance of vermillion The case presented here had all the characteristics described earlier, except for the presence of cytoplasmic inclusion bodies. Bloem et al (1974) also failed to demonstrate cytoplasmic inclusion bodies in their cases.

Pohjanpelto et al (1967) believed that some virus may be the aetiological factor in the development of these growths. No virus, however, could be isolated in our case in agreement with the findings of Bloem et al. (1974) Some abnormal maternal hormone circulating in the blood of the new born has been presumed to play a role in the appearance of these tumours immediately after birth as the tumours quite often regress spontaneously later on (Stout 1975, Grunnet et al 1973, Bloem et al. 1974) Bloem et al (1974) recommended conservative treatment Recurrence has been reported even after excision (Jensen et al. 1957, Shapiro 1969).

REFERENCES

Ahlqvist, J , Pohjanpelto, P , Hjelt, L & Hurme, K (1967) Recurring digital fibrous tumour of childhood Clinical and morphological aspects of a case *Acta path microbiol. scand* **70,** 291–296

Battifora, H & Hines, J R. (1971) Recurrent digital fibromas of childhood *Cancer* **27,** 1530–1536

Bloem, J J , Vuzevski, V. D & Huffstadt, A. J C (1974) Recurring digital fibromas of infancy *J Bone Jt Surg* **56-B,** 746–751

Burry, A. F , Kerr, J F R. & Pope, J H (1970) Recurring digital fibrous tumour of childhood An electron microscopic and virological study *Pathology* **2,** 287–291

Grunnet, N , Genner, J , Mogensen, B & Myhre-Jensen, O (1973) Recurring digital fibrous tumour of childhood. *Acta path micro- scand* (Sect A) **81,** 167–173

Jensen, A. R., Martin, L. W & Longmo, L (1957) Digital neurofibrosarcoma in infan *Paediat* **51,** 566–570

Pohjanpelto, P , Ahlqvist J., Hurme, K & R L (1967) Recurring digital fibrous tumo childhood 2. Isolation of a cell transfor agent *Acta path microbiol scand.* 297–299

Reye, R. D K. (1965) Recurring digital fib tumours of childhood *Arch Path* 228–231

Shapiro, L. (1969) Infantile digital fibrom and aponeurotic fibroma. *Arch. Derm.* 37–42.

Stout, A P (1954) Juvenile fibromatoses Ca **7,** 953–978

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CURRENT ULNAR NERVE DISLOCATION AT THE ELBOW

ort of a Non-Traumatic Case with Ulnar Entrapment Neuropathy

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An unusual case of habitual recurrent ulnar nerve dislocation at the elbow is described The case was complicated by non traumatic ulnar entrapment neuropathy interfering with the patient's profession as a musician (cello)

Key words ulnar nerve, recurrent dislocation, non traumatic entrapment neuropathy

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reported incidence of habitual ulnar nerve ocation varies between 2 and 19 per cent linet 1896, Momberg 1903, Dubs 1918, nan & Surtro 1939, Childress 1956) ocation to the extent of complete forward tion at the internal condyle of the humerus be present without causing any ptoms and without the knowledge of the ndual The lower incidences include only plete dislocations (Cobb 1903) The higher lences include complete as well as mplete dislocation

is suggested that recurrent dislocation of ulnar nerve at the elbow arises as a result auma but can also occur nontraumatically b 1903) In the latter case it is called ntual', "congenital" or "idiopathic" cation.

ases of 'habitual" dislocation are, however, h more common than the traumatic ones ally the affected person is only aware of habitual dislocation when an ulnar apment neuropathy is present

lnar nerve neuritis is thus a rare diagnosis onnection with habitual dislocation of the r nerve unless it is combined with trauma paper reports, however, a case of non-traumatic ulnar nerve neuritis in a patient with habitual dislocation The disability was so great that it was necessary to perform an ulnar nerve transposition The diagnosis and the operative procedure is discussed

CASE REPORT

The patient was a 21-year-old student of music and [illegible] healthy He [illegible]

into the horizontal plane with the elbow [illegible] 90° holding the chords there was a slowly progressing sensation of numbness occurring in his ulnar fingers and pain at the elbow The same sensations occurred in his right arm when using the bow (Figure 1) There was no history of trauma to the elbows.

Clinical examination revealed the ulnar nerve sliding in front of the ulnar epicondyle when the elbows were flexed Registration of the conduction velocity in the ulnar nerve at the elbows (Table 1) comparing elbows flexed and elbows fully extended showed a decrease in the conduction velocity on both sides with the elbows in 90° flexion. With the elbows extended the patient did not feel any sensations in the arm or hand, nor could any

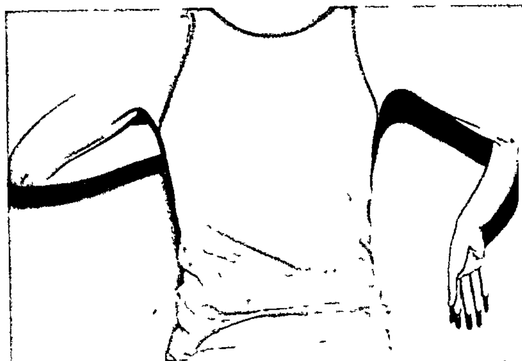


Figure 1 The position of the arms when playing the cello Note the scars after the ulnar transpositions

decreased sensibility in the ulnar nerve area be found X-ray examination of the elbows showed no . There were no symptoms or signs of er possible causes of the pain such as rheumatoid arthritis (Chang et al 1972), post-traumatic arthritis, cervical syndrome, etc

The patient was operated on with transposition of the ulnar nerve on both sides The operation was performed in a bloodless field The nerve was dissected free for about 5 cm proximal and distal to the ulnar epicondyle, mobilized and adapted in front of the epicondyle The adaptation was made by a few sutures in the soft tissues around the nerve Mobilization was started immediately after the operation

Four weeks postoperatively the patient was to take up his cello playing again, now w discomfort A second nerve conduction test made 6 weeks after the operation using the procedure as before the operation This showed no significant difference in the conduc velocity of the ulnar nerves on either side w elbows to flexed 90° and in full extension.

DISCUSSION

Complaints of numbness in the ulnar area both hands are very common in orthop

Table 1 Ulnar nerve conduction

		Full extension in the elbow	90° flexion in the elbow
Preop test	Right	67 m/second	57 m/second
	Left	67 m/second	52 m/second
Postop test	Right	•63 m/second	62 m/second
	Left	•74 m/second	79 m/second

• Nerve conduction values obtained on various occasions from the same nerve can differ depending on the position of the electrode

ctice This particular person – being a sician – certainly found it disturbing to his ying of the cello Having diagnosed an ulnar ve neuritis on the basis of recurrent locations of the nerve it was necessary to form an ulnar nerve transposition ansposition of the ulnar nerve is a simple rative procedure However, perhaps it uld be of value to point out some details of operative procedure and the postoperative e The nerve should be dissected free a ficient distance proximally and distally to epicondyle so that it is possible to place the ve in its new position without stretching it armonth 1943, Childress 1956, Levy & felberg 1972) Moreover, we do not rocate any form of firmer fixation of the ve to keep it in the anterior position Such cedures involve the risk of the development strangulating fibrotic processes We think it very important also to start exercises nediately after the operation in order to vent scar fixation around the nerve

Childress (1956) classified ulnar nerve ermobility into two groups: type A and e B In type A the nerve moves out of its it-condylar groove on the tip of the humeral condyle when the elbow is maximally ted, i e, subluxation occurs in extreme tion. Type B hypermobility means that the rve passes completely across and anterior to epicondyle when the elbow is flexed more n 90°

Our case had a hypermobility of type B pe B possesses greater mobility and is said be more susceptible to friction neuritis obb 1903, Dubs 1918, Learmonth 1943, ildress 1956) This theory is supported by case

Childress (1956) found ulnar nerve dislocations in 16 2 per cent of 1,000 selected individuals (2,000 ulnar nerves), none of whom knew that he had such an anomaly Momberg (1903) discovered in the military hospital in Spandau an incidence of the anomaly of 19 8 per cent among 140 soldiers. In non-traumatic cases of habitual ulnar nerve dislocation it is known that severe symptoms rarely occur and there is seldom need for operative intervention It is the traumatic cases which give rise to all the cases which have been operated on with a few exceptions such as in our case.

REFERENCES

Burman, M S & Surtro, C J (1939) Recurrent luxation of the ulnar nerve by congenital posterior position of the medial epicondyle of the humerus. *J Bone Jt Surg* 21, 958–962.

Chang, L W, Gowans, J D C, Granger, C V & Millener, L. H (1972) Entrapment neuropathy of the posterior interosseous nerve A complication of rheumatoid arthritis. *Arth and Rheum.* 15, 350–352.

Childress, H M (1956) Recurrent ulnar nerve dislocation at the elbow *J Bone Jt Surg* 38 A, 978–984

Cobb, F (1903) Report of a case of recurrent dislocation of the ulnar nerve cured by operation *Ann Surg* 38, 652–663

Collinet, P (1896) Luxation congenital du nerf cubital *Bull Soc Anat de Paris* 71, 358–361

Dubs, J (1918) Uber die Traumatische Luxation des Nervus Ulnaris. *Corresp Bl. schweiz Arz* 48, 1711–1718

Learmonth J R (1943) A technique for transplanting the ulnar nerve *Surg Gynec Obstet* 75, 792–801

Levy D M & Apfelberg D B (1972) *Results of* anterior transposition for ulnar neuropathy at the elbow *Amer J Surg* 123, 304–308

Momberg Stabsarzt (1903) Die luxation des Nervus Ulnaris. *Arch klin Chir* 70, 215–232.

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ABDUCTION CONTRACTURE OF THE SHOULDER

A Report of Two Patients

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Two cases of winged scapulae due to fibrosis of the deltoid muscle are reported The fact that these two patients were healthy and well prior to injections suggests that intramuscular injection is the causative factor Treatment by simple division is satisfactory

Key words contracture, deltoid muscle, fibrosis intramuscular injection, winged scapulae

Accepted 29 xii 77

Contracture and limitation of major peripheral joints due to adjacent in- ' fibrosis has been reported with increasing frequency Altered knee motion caused by quadriceps fibrosis has been well described and documented However, only ten patients with fibrosis of the deltoid muscle leading to abduction contracture of the shoulder have been reported (Bhattacharyya 1966, Hill et al 1967, Goodfellow & Nade 1969, Wolbrink et al 1973, Branick et al 1976) We are presenting two additional cases and our experience with this peculiar deformity

CASE REPORTS

Case 1 A 9-year-old girl was seen with prominence and winging of both scapulae The deformity was accidentally detected by an elementary school teacher who found that the patient had difficulty in bringing both of her arms to the torso She had always been well except for upper respiratory infections during childhood. Her history also revealed that she had received a number of intramuscular injections into her deltoid regions with each transient illness. Inspection showed prominent scapulae in the standing position with a depressed groove at the site of the intermediate and posterior parts of the deltoid muscle (Figure 1A). A hard band-like structure was palpable in the depressed groove between the acromion and the deltoid tubercle of the humerus. The range of motion of both shoulders was free except for a bilateral abduction deformity, i.e. loss of ability to bring the arms to the sides of the trunk (Figure 1B). Winging of the scapulae was exaggerated by shoulder adduction Significant ... shoulder joints was not seen roentgenographically.

Bilateral exploration of the deltoids showed a fibrous band in the intermediate part of the muscle The band originated at the scapular spine and acromion, extending to the insertion of the humerus. Transverse division of the fibrous band and gentle graduated adduction of the arm immediately relieved the abduction deformity Microscopic examination showed fibrosis. Postoperative mobilization of the shoulder

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e 1A The winging of the scapulae with ssion of the deltoid is clearly shown

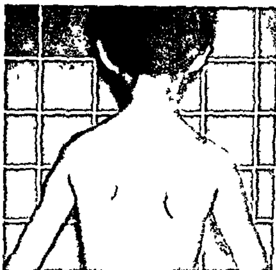
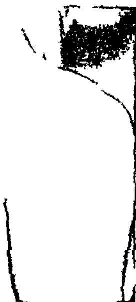


Figure 1B The patient is unable to bring the arms to the torso



'e 2A The groove in the mid-portion of the id is evident

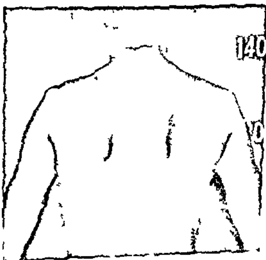


Figure 2B The patient cannot bring her arms to the chest wall and the medial borders of the scapulae are prominent

began as soon as the patient was able to tolerate it. Follow-up at 2 years showed the abduction deformity was absent in both shoulders and there was full range of motion.

Case 2 A 43-year-old housewife was seen with a 1-year history of winging of both shoulder blades which disturbed her sleep because of pain in the area of the medial angle of both scapulae. About 1

injections in both deltoid muscles for the past 2 years for a purported chronic anemia. No similar deformity was noted in the other family members. On examination a groove over the middle deltoid extending from the acromion to the deltoid tubercle of the humerus was noted (Figure 2A). There was also accompanying winging of the scapulae (Figure 2B) which was most prominent on adduction of the arm and disappeared upon elevation of the arm to approximately 60° Adduction of the arms was blocked by a fibrotic band at 30° of fixed abduction. The range of motion of the shoulders was otherwise normal.

Exploration of the deltoid muscles revealed a tight band extending from the acromion to the humerus. Simple division of this band did not fully correct the deformity in either shoulder By gentle adduction of the arms several tight fibrous bands were palpable in the middle portion of each deltoid muscle. Release of the contracture was only after division of the bands. A portion fibrous tissue was resected and microscopic showed degeneration of the muscle es and fibrosis. No immobilization carried after surgery The shoulders were, for all intents and purposes,

DISCUSSION

Abduction contracture of the winging of the scapulae is a due to fibrosis of the deltoid muscle the original report of three cases (Sato et al), an additional seven cases been published (*Bhattacharyya 1966*, al. 1967, Goodfellow & Nade 1969, Wo et al 1973, Branick et al. 1976). deformity is comparable to that of quadriceps fibrosis (Gunn 1964). Several causative factors suggested from the reports include developmental defect (Wolbrink et al 1973) congenital progressive fibrosis (Bhattacharyya 1966), and injection (Gunn 1964 Br al. 1976).

Intramuscular injections are give quently by local practitioners in this One of the present authors (YSH) h collected 24 cases of fibrosis of the muscle (Hang 1978), resulting in an abd external rotation and extension hip def This allied disorder has been seen increasing frequency The two cases re here, together with recent observatio patients with gluteal fibrosis, strongly s *that repeated intramuscular injections* an important causative factor The absen similar affection in other family memb these two patients more or less precl genetic origin.

Simple division of the fibrotic ba adequate, although *excisional resection* band has been recommended by (Bhattacharyya *1966*, *Hill et al* Wolbrink et al. 1973). This clinical en *amenable only* to surgery and the res satisfactory We believe *the condition* more commonly than has been docume

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racture of one knee secondary to partial muscle fibrosis. A case report. *J Bone Jt Surg* 49-A, 961–964
o, M., Honda, S & Inoue, H (1965) Three cases of abduction contracture of the shoulder joint caused by fibrosis of the deltoid muscle *Orthopaedic Surgery (Tokyo)* **16**, 1052–1056
Wolbrink, A J, Hsu, Z & Bianco, A J (1973) Abduction contracture of the shoulders and hips secondary to fibrous bands. *J Bone Jt Surg* 55-A, 844–846

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LUMBAR INTERVERTEBRAL DISC HERNIATION IN THE YOUNG

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A survey of 37 young patients, 10 to 18 years of age, with [illegible] tervertebral disc herniation is presented. Local physical findings and [illegible] tion in straight leg raising are often more marked in the young [illegible] adults, whereas pain may be slight or even absent. Neurological [illegible] [illegible] surgical treatment good results were obtained in nearly all cases.

Key words: disc herniation lumbar spine, children adolescents

Accepted 17.x.77

ahren in 1946 was the first to report surgical treatment for lumbar intervertebral disc herniation in a child. Since then few papers on this subject have appeared in the literature. Lumbar disc herniation in children and adolescents is uncommon, the incidence varies between 0.4 per cent (Webb et al. 1954) and 1.3 per cent (O'Connell 1960) of all cases of disc herniation.

Our impression is that recognition of this syndrome often is delayed in teenagers. The reason may be that symptoms and signs in this age group differ from those in adults, as found by Rugtveit (1966) and Day (1967). Because of its rarity physicians may pay too little attention to this syndrome in the young (Weiss & Raskind 1967, Bradford & Garcia 1971).

The purpose of the present investigation is to draw attention to this condition in young patients, in order to encourage earlier diagnosis and treatment.

MATERIAL AND METHODS

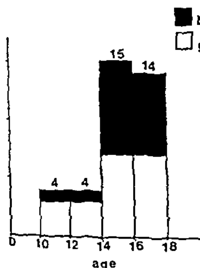
The material consists of 37 cases of lumbar [illegible] vertebral disc herniation in patients [illegible] years of age, treated in Sophies [illegible] Orthopaedic Hospital or in Kronpr[illegible] Martha's Institute from 1965 to 1976. During [illegible] same period a total of 1016 patients [illegible] for sciatica.

All of the 37 patients were examined by [illegible] perienced neurologist, and in all a radiculog[illegible] was performed. In 36 patients the diagnosis [illegible] verified by operation. One patient with [illegible] clinical findings and a positive radiculog[illegible] refused operative treatment.

All patients were given a follow-up exam[illegible] The survey is based on information obtained [illegible] the records and a re-examination of [illegible] radiographs.

RESULTS

The age and sex distribution is [illegible] Figure 1. The two youngest patien[illegible]



re 1 Age and sex distribution in 37 patients lumbar intervertebral disc herniation.

s old. Serious low back pain sciatica or , were the main symptoms in 24 patients e nine felt only slight pain, and four had pain at all (Table 1). In eight cases the was localized to the leg only Postural urbances were the major complaint in patients, back stiffness in three and gait blems in one of the patients.

en of the patients had a history of major ma.

he duration of the symptoms before ative diagnosis and treatment varied ween 3 months and 6 years on average 20 nths.

he correct diagnosis was made by the rring physician in only 14 of the patients, le scoliosis was suggested in 9 cases ble 2).

linical examination revealed abnormality posture, spasm of the erector spinae cles and reduced mobility of the spine in patients (Table 3) Nineteen presented an obvious scoliosis. A distinct kyphosis found in six patients and the rest had eased or straightened out lumbar lordosis. straight leg raising test was positive in ases being limited to 30° or less in 34 s. A crossed positive elevation test of 80° was found in 24 patients. Three patients had a markedly restricted straight-leg raising test without any feeling of pain

Neurological examination was completely normal in 15 patients (Table 3) When a neurological deficit was found it was usually of a minor nature

Radiographs of the lumbo-sacral spine revealed congenital abnormalities in 12 patients, asymmetry of the distal lumbar vertebra in eight and spina bifida in four cases. Radiculography was positive in all patients, at the L4–L5 level in 22 and at the L5–S1 level in 15 In a few patients a short and widened nerve root sheath was the only pathological finding

Conservative treatment was tried initially in 29 of the patients. Eventually all but one were treated surgically A laminectomy was performed at one level, on one or both sides. Operative findings correlated well with the radiculographs. Free disc herniation or definite disc protrusion were found on one side only in all cases. In two patients the bulging disc contained a grumous fluid Histological examination of the removed disc was not performed

Table 1 Dominating symptoms in 37 young patients with lumbar intervertebral disc herniation.

Pain		24
Back pain only	7	
Back pain and leg pain	9	
Leg pain only	8	
Postural disturbances		9
Back stiffness		3
Gait problems		1

Table 2 Diagnosis on referral in 37 young patients with lumbar intervertebral disc herniation

Sciatica	14
Scoliosis	9
Back pain	5
Leg pain	3
Abnormal gait	2
Back stiffness	2
Hip disease	1
Bechterew's disease	1

Table 3 Comparison of the physical findings in teenagers and lumbar intervertebral disc herniation

	Present series (37 young people)		Røvig (1949) (100 adults)
	No	Per cent	Per cent
List			93
List or scoliosis	37	100	
Distinct scoliosis	19	51	
Kyphosis or decreased lumbar lordosis	37	100	88
Reduced mobility of spine	37	100	100
Muscle spasm	37	100	100
Straight-leg raising positive	37	100	98
Straight-leg raising 30° or below	34	92	56
Abnormal gait	9	24	
Neurological findings			
Normal	15	41	
Muscle atrophy or hypotony	16	43	94
Paresis	11	29	38
Sensory deficit	8	21	76
Depressed or absent tendon reflexes	4	10	54
Disturbance of bladder function	0		12

There were no surgical complications, and the immediate result was most satisfactory as far as relief of pain was concerned The spinal contractions gradually disappeared spontaneously in all but one patient, whose persisting [illegible] was treated successfully by a corrective plaster cast (Figure 2)

The follow-up period ranged from 10 years to 6 months with an average of 5 years and 6 months The result was good in 31 patients who had no subjective symptoms and normal objective findings Five patients had minor complaints One patient had relapse of back pain and sciatica and was reoperated a few months after primary surgery Radiculography showed changes suspected of being disc herniation at the same level as before At surgery nerve root adhesions were found, but no disc herniation or protrusion

DISCUSSION

The proportion of teenagers among all patients treated for lumbar intervertebral disc herniation was 3 6 per cent which is relatively high However, a selection has probably [illegible] place, because patients with scoliosis [illegible] other special back problems have [illegible] referred to our hospitals from regions [illegible] the ordinary referral area. There was a [illegible] preponderance of females, whereas males [illegible] dominate in most other series of disc [illegible] tion in both young people (Bradford & G[illegible] 1971) and adults (Røvig 1949).

Trauma was frequently present [illegible] history of our patients. Most authors [illegible] made the same observation.

Nelson et al (1972) found no [illegible] difference in the occurrence of trauma [illegible] precipitating factor in disc disease [illegible] young people and adults Trauma is [illegible]

Figure 2 An 11-year-old boy referred [illegible] diagnosis of scoliosis He had no pain at [illegible] presented with a left sided [illegible] scoliosis of 30° (a,c) and spasm of the [illegible] spinae muscles The straight-leg raising [illegible] positive at 10° Radiculography showed [illegible] herniation on the right side at the L4–L5 [illegible] Three months after surgery the [illegible] unchanged, but the spine straightened after [illegible] ment in a corrective plaster cast (d)







not the only cause of intervertebral disc herniation, as the disc is not the weakest part of the spine (Brown et al 1969), and disc *degeneration may start early in life*

Conflicting information exists as to whether or not symptoms and signs differ in children and adult patients suffering from intervertebral disc herniation Some authors have stressed that while symptoms are often minor, objective findings dominate in children (Rugtveit 1966, Day 1967) Others have found no significant differences between *young people and adults as regards symptoms* and signs (Epstein & Lavine 1964, Weiss & Raskind 1967)

Pain was the main symptom in only 24 of our patients, four had no pain at all, whereas pain is the dominating complaint in nearly all adult patients (Røvig 1949) Other discomforts such as postural disturbances and back stiffness are also felt in the great *majority of adults.*

Clinical examination revealed impressive pathological findings in all cases, viz scoliosis, kyphosis or reduced lumbar lordosis, limitation of spinal movement and muscle spasm A markedly restricted straight-raising test was also typical in cases of intervertebral disc herniation in young patients The test was positive also in patients without irradiating pain, and limitation was not always accompanied by pain Similar observations were made by Key (1950)

Røvig (1949) made a clinical study of 100 adult patients with lumbar intervertebral disc herniation He also found distinct physical signs (Table 3) However, obvious scoliosis and markedly restricted straight-leg raising test were more frequent in younger patients, while positive neurological findings were more frequent in adults In our series the neurological deficits were of little significance

Though there are no essential differences in symptoms and signs in young as opposed to adult patients with disc herniation, it seems that local physical findings and limitation in straight-leg raising tend to be more marked while pain may be slight or even absent in young people Also there is an [illegible] contrast between the clinical impression of nerve root compression and the [illegible] *neurological deficits in teenagers* The differences in the symptoms and signs in the two age groups may be explained by the mobile spine of the young prevent pressure

The intervertebral disc hern[illegible] syndrome in children and adolescen[illegible] characteristic, and it should not be diffic[illegible] recognize provided awareness of *syndrome is aroused*

It is our experience that [illegible] treatment often fails in teenagers. The r[illegible] of surgery, however, were gratifying Th[illegible] in accordance with most authors ([illegible] al 1972, Bulos 1973) though Taylor ([illegible] found that the results of surgery wer[illegible] from satisfactory

REFERENCES

Bradford, D S & Garcia A. (1971) Lumb[illegible] tervertebral disc herniations in childre[illegible] adolescents. *Orthop Clin N Am* [illegible] 583–592.

Brown, T, Hansen R. J & Yorra A. J ([illegible] Some mechanical tests on the lumbo[illegible] spine and particular reference to th[illegible] *tervertebral disc J Bone Jt Surg* [illegible] 1135–1164

Bulos, S (1973) Herniated intervertebral [illegible] disc in the teenager *J Bone Jt Surg* [illegible] 273–278

Day, P L (1967) The teenage disc [illegible] *Sth med J (Bgham Ala)* 60, 247 250

Epstein J A & Lavine L S (1964) [illegible] lumbar intervertebral disc in teen-age [illegible] *J Neurosurg* 21, 1070–1075

Key, J A (1950) Intervertebral – disc [illegible] children and adolescents. *J Bone Jt Surg* [illegible] A, 97–102

Nelson C L, Janecki C. F., Gildenberg, P [illegible] Sava G (1972) Disc protrusions in the [illegible] *Clin Orthop* 88, 142–150

O Connell, J E A (1960) Intervertebral di[illegible] *trusions in childhood* and adolescence [illegible] *Surg* 47, 611–616

Røvig, G (1949) Rupture of lumbar disc [illegible] traspinal protrusion of the nucleus p[illegible] clinical study *Acta chir scand.* [illegible]

Rugtveit, A (1966) Juvenile lumbar [illegible] herniations. *Acta orthop scand.* 37 [illegible]

T h. F (1971) Intervertebral disc ıpse ın children and adolescents. *J Bone urg* 53-B, 357

, H. (1946) Herniated nucleus pulposus ın ld of twelve years. *Acta orthop scand* 16, 42

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REFERENCES

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Bulos, S (1973) Herniated intervertebr disc in the teenager *J Bone Jt Su* 273–278

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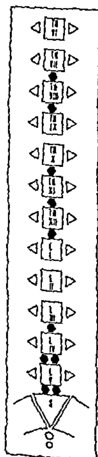
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he sites of pyogenic spondylitis

The course of the disease Three patients became acutely ill with septic fever and back pain In these cases blood culture was positive. In the remaining cases the onset of the disease was insidious

Symptoms The general symptoms were fever weight loss and fatigue An acute onset of the disease was associated with septic fever (40°C) In the insidious cases the patients were subfebrile All patients had back pain, which usually was localized. This was the symptom for which the patients consulted a physician.

The primary focus The possible primary focus of bacteraemia was revealed by the history in three cases. One patient had had tonsillitis 6 weeks before the onset of symptoms. Another patient had caught erysipelas of the hands 2 weeks before the onset of symptoms, and a third patient had had a tooth fixed 10 days before the symptoms began.

Predisposing factors Factors predisposing to infection were present in four cases. One patient showed agranulocytosis due to thyrostatic therapy Two patients had latent diabetes, and one was a chronic alcoholic.

Physical findings Percussion revealed local tenderness at the site of infection in all patients. Neurological signs were found in two patients. One had transient signs originating in the cauda equina, the other showed a hyper-reactive Achilles reflex.

Laboratory findings The ESR was clearly elevated in all patients, the values ranged from 66 to 141 Slight anaemia (<120 g/l) was observed in seven

Table 1 Short case histories

x	Age	Local symptoms	General symptoms	Predisposing factors	Interval between presenting symptoms and diagnosis (months)
	32	Back pain	Fever	Agranulocytosis	2
	54	Back pain	Fever	–	3
	36	Back pain	Fever Weight loss Fatigue	Chronic alcoholism	5
	62	Back pain	Weight loss	Latent diabetes	3
	17	Back pain	Fever	–	1
	54	Back pain	Weight loss	–	4
	38	Back pain	Fever Weight loss	–	1
	33	Back pain	Fever	–	1 5
	62	Back pain	Fever	Latent diabetes	3
	78	Back pain	Fever	–	

and mild leucocytosis (>10 000) in four cases. The patient showing agranulocytosis had a haemoglobin value of 76 when it was at its lowest but this was attributed to his haematological disease rather than to the infection Alkaline phosphatase was elevated in six patients.

Bacteriology Blood culture was positive in three patients. *Staphylococcus aureus* was identified in two cases *Streptococcus faecalis* in one. A sample of pus from the site of infection was obtained at exploration in one case. *Staphylococcus aureus* was demonstrated on culture of this sample The ASTA values were elevated (≥4) in eight cases (range 4 to 32)

Radiological findings Narrowing of an intervertebral space was observed in all patients (Figure 2) A wedge-shaped deformity was noticed in three patients and an abscess shadow in two

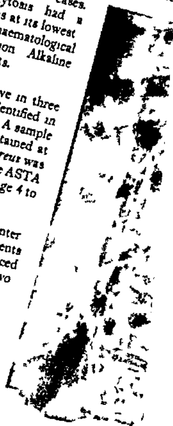


Figure 2b



Figure 2 36-year old male (R R) who became acutely ill with septic fever and back pain (a) Two weeks after the onset of symptoms slight narrowing of an intervertebral space (b) Five weeks f… onset of symptoms vertebral coll… vertebral body resultin… Eleven mont…

of the vertebral bodies varying in degree observed in eight patients during an ation period of 6 to 30 months.

ctive isotope scanning Scanning with Tc⁹⁹ rried out in nine patients, seven of whom t an early stage of the disease A significant was noticed in five of these cases

verage interval between the onset of ms and the diagnosis was 3 months, range 1 onths. All patients were hospitalized for 3 efore a definite diagnosis could be made

ent All patients were admitted to the aedic Department In the early stages of the the treatment consisted of bed rest and tics. The average duration of hospital nt was 64 days, range 36 to 99 days. tics were given for 142 days on the average rom 45 to 321 days. If blood culture was the choice of antibiotic depended on the ination of resistance Otherwise an ic generally known to be effective against *lococcus aureus* was given, e.g Cloxacillin®, ysin® or Erythromycin® The patients led favourably to the treatment all recovered ame symptom free

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isly, febrile patients with a high ESR ave been treated with antibiotics for a ime without any knowledge of the infection of the spine and may thus ecome symptom free under a wrong sis. It is also possible as Martin (1970) ed, that many patients who in the past reated for tuberculous spondylitis and red rapidly did, in fact suffer from litis caused by pyogenic bacteria

ecific bacteriological diagnosis must be l When the disease has an acute onset, culture is usually positive If the onset is te blood culture is usually negative performed with a trocar under TV ring is technically difficult, but this l has increased in popularity (Sneppen 1976) The possible complications are palsy and meningitis. Ambrose et al. and Lewis et al. (1972) successfully ed bacterial samples by needle aspiration Holzman & Bishko (1971) disputed the necessity of specific bacteriological diagnosis and resistance determination and thus also of early exploration This standp is justified with regard to the spond addicts These cases are often caused by g a negative bacteria resistant to antibiotics. In Finland, exploration is not absolu necessary, since *Staphylococcus aureus* is the most frequent causative agent and the diagnosis can often be supported by sero bacteriological tests. Von Schwagerl (1969) proved the diagnostic validity of ASTA-determination in deep, progressing infections caused by *Staphylococcus aureus*, especially in spondylitis. A diagnosis based on the clinical course of the disease, the radiological findings and serobacteriological tests will often suffice for the institution of therapy In fact a positive reaction to the therapy is diagnostic. If a malignant or other tumour cannot otherwise be excluded, exploration is of course mandatory

Radiological demonstrable lesions in pyogenic spondylitis may develop very quickly A slower process is an important diagnostic criterion in tuberculous spondylitis. Isotope scanning is of less value diagnostically because the method is non-specific. Still this technique may be used in both the diagnosis and the follow-up of pyogenic spondylitis. It is a good indicator with regard to the reactivation of an infectious process (Kemp et al 1973) and roentgenographically dubious primary lesions and recurrences (Fellander & Lindberg 1966).

The treatment of pyogenic spondylitis is usually conservative, antibiotics and bed rest may be recommended A plaster bed, as was formerly used is not required Operation is indicated if conservative treatment fails and there is progression of neurological signs.

An early diagnosis of the disease is difficult. Fever, back pain, a high ESR, slight anaemia and mild leucocytosis are typical features, but a similar clinical picture is seen in many other diseases, e g, malignant tumours. Because of the general symptoms, the back pain may easily be ignored and the patient may therefore be subjected to unnecessary examinations and

procedures Waldvogel et al (1970) stated that an early diagnosis depends on a clinical suspicion If the diagnosis is made early enough, neurological complications are rare and the prognosis is good

REFERENCES

Ahlback, S, Collert, S & Fellander, M (1973) Ospecifik bakteriell spondylit Diagnostiska synpunker *Svenska Lak-Tidn* 70, 2234–2236

Ambrose, G B, Albert, M & Neer, C S (1966) Vertebral osteomyelitis A diagnostic problem *J Amer med Ass* 197, 101–104

Fellander, M & Lindberg, L (1966) Clinical use of radiostrontium in evaluation of spondylitis *J Bone Jt Surg* 48-A, 1585–1606

Holzman, R S & Bishko, F (1971) Osteomyelitis in heroin addicts. *Ann intern Med* 75, 693–696

Kemp, H B S, Johns, D L, McAlister, J & Codlee, J N (1973) The role of fluorine-18 and strontium-87m scintigraphy in the management of infective spondylitis. *J Bone Jt Surg* [illegible] 301–311

Kido, D, Bryan, D & Halpern M [illegible]

[illegible]

study of the results of treatment during th[illegible] twenty five years *J Bone Jt Surg* [illegible] 613–628

Schwagerl, W von (1969) Die klinisch-prak[illegible] Bedeutung der Antistaphylolysin-[illegible] (ASTA-) Bestimmung bei orthopä[illegible] Erkrankungen *Z Orthop Traum.* [illegible] 144–151

Serre, H, Blotman, F, Sany, J & Simon, L [illegible] Spondylodiscites infectieuses A[illegible] symptomatiques et évolutifs. *Rev Rh*[illegible] 243–253

Sneppen, O, Klaumann, U, Kofoed, [illegible] Heerfordt, J (1976) Uspesifik h[illegible] spondylitis Diagnostik og behandling [illegible] *Laeg* 138, 1708–1712

Waldvogel, F A, Medoff, G G & Schwartz, [illegible] (1970) Osteomyelitis review of clinical fe[illegible] therapeutic considerations and unusual as[illegible] in three parts. *N Engl J Med* 282, 19[illegible]

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)NE SCINTIGRAPHY IN EARLY DIAGNOSIS OF :RTHES' DISEASE

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^{99m}Tc-pyrophosphate bone scintigraphy was performed in patients with Perthes' disease in the radiological initial stage and within 4 months after the onset of symptoms, and in patients with transient synovitis of the hip joint. In Perthes' disease there was decreased activity in the capital femoral epiphysis. In cases with synovitis a diffusely increased activity was found. A correct diagnosis of Perthes' disease was possible at a time when the radiological findings were minimal or even prior to any radiological findings. Increased activity might have been expected if the aetiology of the disease was an aseptic coxitis, or if the increased radiological density was due to new bone formation Also in abortive forms of Perthes' disease a decreased activity was found This indicates that a period of decreased blood flow to the epiphysis is not bound to be followed by the typical radiological course of the disease

Key words bone, epiphysis, hip, Legg Perthes' disease, osteochondritis, necrosis, radioisotopes

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ɔe pathology of Perthes' disease can be ·scribed as a vascular disturbance leading to ·crosis and subsequent revascularization of e capital femoral epiphysis (Jonsäter 1953, cKibbin & Ráliš 1974, Jensen & Lauritzen 76) Death of bone does not produce ımediate changes in its radiographic density ıd in the early stages standard radiographs e normal. Therefore diagnosis and ·atment are often delayed To establish an rly diagnosis of bone necrosis, bone isotope chniques have been tried for many years 'ucker 1950), but were not generally cepted for clinical use until the introduction ^{99m}Tc labelled bone seeking components.

The degree of tracer uptake is primarily a function of the blood supply to the bone (Garnett et al 1975), and may thus be used for the detection of areas with both decreased and increased vascular supply This method has been used successfully in studying necrosis of the femoral head following fractures (Korvald & Sundsfjord 1974) The radiation dose is low and the method can therefore be used in investigating paediatric bone diseases as well. The purpose of the present paper was to investigate the possibility of using bone scintigraphy to make an early diagnosis in Perthes' disease.

MATERIAL AND METHODS

From 1974 to 1977 bone scintigraphy was performed in patients with suspected Perthes' disease. They were examined clinically, radiologically and with bone scintigraphy as early as possible Only patients examined within the first 4 months after the onset of symptoms, having either radiographical signs of Perthes' disease in the initial stage or no positive radiographical findings at all, a total of 26 patients, were included in the present material. However, two patients were excluded because scintigraphic images were not taken with the hips in the standard position, leaving a total of 24 patients for further study

^{99m}Tc-pyrophosphate was prepared by adding 5 ml saline eluate from a ^{99m}Tc generator to the contents of a bottle of Isokit Nyco containing polyphosphate 2.4 μmol, Na-pyrophosphate 22.4 μmol, Sn^{II} (as chloride) 2.2 μmol. Each patient [illegible]

encouraged to drink a lot to reduce the concentration in the urogenital tract, and to urinate frequently to minimize the radiation in the bladder No adverse reactions to the injected pharmacon were observed The scintigraphic examination was performed with a gamma-camera (Pho/Gamma III, Nuclear Chicago) connected to a computer unit (Nuclear Data, fifty fifty MED) Bone scintigraphic [illegible] were taken of the pelvis and both hips with a [illegible] hole collimator, and of both hips in [illegible] position using a pinhole collimator When using the parallel hole collimator it was possible to [illegible] the uptake of the tracer in the two hip regions [illegible] detailed study of the radioactivity in the [illegible] was possible using the enlarged image [illegible] with the pinhole collimator In normal [illegible] scintigrams the acetabular roof and the [illegible] plates reveal a high activity, whereas the [illegible] epiphysis and the femoral neck show a [illegible] lower uptake (Figure 1)

RESULTS

Perthes' disease developed in 20 hips of [illegible] out of the 24 patients. Three were [illegible] and 15 males The age varied from 2½ to [illegible] years, mean age 5 4 years. The right hip was involved in 13 cases and the left hip in [illegible] cases. The patients presented with a [illegible] and/or pain in the involved hip. The [illegible] duration of symptoms was 2.6 months. [illegible]



Figure 1 A 7-year-old boy with pain in the left hip region for about 2 months and restricted [illegible] the hip joint (a) Radiograph reveals no pathological findings (b) The bone scintigraphic image [illegible] pinhole collimator showed slightly increased activity in the hip region, but no areas [illegible] uptake of tracer The acetabulum, femoral head, epiphyseal plate and greater trochanter [illegible] identified.

ıge of movement of the affected hip joint ıs reduced. Radiographs showed Perthes' ease in the initial stage in 18 hips, 13 of uch showed sclerosis. Normal radiographs the first examination were found in two ›s.

Scintigraphy revealed a pathological uptake th *decreased activity* in the capital femoral iphysis in all cases with Perthes' disease. creased radioactivity throughout the entire iphysis was observed in half of the hips igure 2) The others had decreased activity parts of the epiphysis. Increased activity in : hip region was not observed in any case th Perthes' disease in the early stage inrtigated.

Three patients had radiographically uniral Perthes' disease at the *first* examina- whereas scintigraphy revealed distinctly creased activity in *both* hips. In one case igure 3) symptoms had been present for 1 nth in the radiographically normal hip Later on, radiographs showed both hips passing through the usual stages of fragmentation and remodelling In a second patient, with symptoms from one hip only, radiographs showed bilateral involvement 4 months later In the third patient, no radiographical changes nor any symptoms developed in the hip with decreased scintigraphical activity only

No radiological signs of Perthes' disease were found in six patients at the time of scintigraphy Radiographs at follow-up 4 months later were normal as well. All suffered from limping and/or pain Decreased mobility of the hip joint was demonstrated in all these cases and in two patients the decreased mobility remained at the time of scintigraphy Scintigraphy revealed no signs of decreased uptake of the tracer On the contrary a slightly *increased activity* affecting both the proximal femoral epiphysis, the metaphysis and the acetabulum was found (Figure 1)



2 *A 4-year-old boy who had been limping with his left leg for about 2 months (a) Radiograph of left hip shows Perthes' disease in late initial stage with sclerosis and slight flattening of the ysis (b) The bone scintigraphic image with a pinhole collimator shows decreased activity in the ole epiphysis*

3a

Figure 3 A 3 ... left hip (a) Ra ... right hip is no ... left capital epip ... but also in the right radiologically normal hip

DISCUSSION

In Perthes' disease symptoms and clinical findings are not conclusive, and *diagnosis* is based on radiographs only However, the earliest radiographical changes are usually first seen several weeks after onset of symptoms (Edgren 1965) In the present investigation it has been possible to demonstrate a pathological scintigram in cases of Perthes' disease examined during the first 4 months after onset of symptoms

and a decreased uptake of ^{99m}Tc-phosphate in all or part of the capital ral epiphysis. These findings which rm the results of Danigelis et al (1975), e present before any changes could be on radiographs.

he exact location of ^{99m}Tc-pyrophosphate one is unknown, but it seems to be linked he hydroxyapatite crystals (Garnett et al. 5, Greif 1976). The degree of uptake ably depends on many factors such as e capillary permeability and receptors able But the degree of regional bone d flow is a major determinant for the ee of tracer uptake (Siegel et al 1976) decreased uptake in Perthes' disease may fore be a sign of decreased blood flow to epiphysis. If the onset of symptoms is ed to a vascular disturbance leading to rosis of the epiphysis it is reasonable to me that ^{99m}Tc-pyrophosphate uptake eases immediately after the impairment he blood supply A positive scintigraphic mination should therefore be expected at very beginning of the symptoms, and e scintigraphy may thus be of great importance in the early diagnosis of Perthes' ease

The cause of the radiological sclerosis in initial stage of Perthes' disease has been a tter of dispute (Jonsäter 1953, Larsen & man 1973) In an investigation using F^{18} ntigraphy, Bohr (1973) found increased take even in the initial stage and supported opinion that the increased density was e to appositional bone formation. In the sent material the examination did not ow any sign of increased activity in any rts of the capital femoral epiphysis even in ses with radiological sclerosis. As F^{18} and Tc-pyrophosphate accumulate in the same eas (Garnett et al. 1975), these two reports em to contradict each other However, the amination with F^{18} was performed latively late and the image possibly represents a phase passing on to the fragmentation stage with revascularization and new ne formation. In the present material the aminations were performed very early in the initial stage within 4 months of the onset of symptoms and prior to any revascularization and new bone formation. The results in this investigation therefore are in agreement with the histological findings of Jonsäter (1953) and indicate an initial phase of decreased blood supply to the epiphysis.

The *aetiology* of the decreased blood flow is obscure Vascular occlusions, alterations in blood coagulability and a relatively insufficient blood supply to a growing epiphysis have been discussed (Hipp 1962, Chung & Ralston 1969, Rodegerdts 1969, Bjerkreim & Trygstad 1976, Jensen & Lauritzen 1976) Furthermore, transient synovitis of the hip joint has been proposed as a cause (Spock 1959, Emr 1966, Barz & Torklus 1976) In the present investigation none of the cases with clinical synovitis had any decrease in the uptake of tracer, on the contrary, some had a diffusely increased uptake often found in cases of inflammatory disease (Hoffer & Genant 1976) The patients with Perthes' disease had no signs of increased uptake of the tracer This would be expected if an inflammatory reaction was the primary cause of the disease

The radiological findings in Perthes' disease change in a rather typical manner with progress and eventual healing of the disorder However, cases with minor radiological changes and a relatively rapid improvement have been described Sundt (1949) called these cases *"abortive" Legg-Calvé-Perthes' disease*, a term also used by Katz (1965) Meyer (1964) named these involvements "dysplasia epiphysialis capitis femoris", and believed they represented a separate syndrome However, it is still uncertain whether this is merely a variant of Perthes' disease or a growth disturbance In the present study one hip had radiographical changes corresponding to an abortive form of Perthes' disease, and the scintigraphic image showed decreased uptake of the ^{99m}Tc-pyrophosphate In another case with decreased uptake in an asymptomatic hip and in whom treatment was started very early owing to involvement of the other hip no

radiographic changes occurred This indicates that abortive forms of Perthes' disease may be caused by vascular disturbances Furthermore, it indicates that a period of decreased blood flow to the epiphysis is not bound to be followed by the typical Perthes' disease which probably is due to a late revascularization and reinfarction (Sanchis et al 1973, McKibbin & Ráliš 1974, Jensen & Lauritzen 1976, Inoue et al 1976)

REFERENCES

Barz, F-B & Torklus, D v (1976) Morbus Perthes Folge einer Synovitis? *Z Orthop* **114**, 116–122

Bohr, H (1973) Densitometry and 18-F scintigraphy in the study of the revascularisation of the femoral head in coxa plana (C-P) *Acta orthop scand* **44**, 417–425

Bjerkreim, I & Trygstad, O (1976) Necrosis of the femoral capital epiphysis occurring during human growth hormone therapy *Acta orthop scand* **47**, 189–192

Chung S M K & Ralston, E L (1969) Necrosis of the femoral head associated with sickle-cell anaemia and its genetic variants. *J Bone Jt Surg* **51**-A, 33–58

Danigelis, J A, Fisher, R L, Ozonoff, M B & Sziklas, J J (1975) ^{99m}Tc-polyphosphate bone imaging in Legg-Perthes' disease *Radiology* **115**, 407–413

Edgren, W (1965) Coxa plana *Acta orthop scand* Suppl **84**, 1–129

Emr, J (1966) Beitrag zur Frage der konstitutionellen und enzundlichen Athiologie der Perthesshen Krankheit *Beitr Orthop Traum* **13**, 694–697

Garnett, E S, Bowen, B M, Coates, G & Nahmias, C (1975) An analysis of factors which influence the local accumulation of bone-seeking radiopharmaceuticals *Invest Radiol* **10**, 564–568

Greif, J (1976) Data to be published Personal communication

Hipp, E (1962) Huftkopfgefässe bei der juvenilen Osteochondrose des Huftgelenkes (Calvé-Legg-Perthes) *Z Orthop* 96 (Beilageheft) 6[illegible]

Hoffer P B & Genant, H K [illegible] Radionuclide joint imaging *Semin Nucl* [illegible] 6, 121–137

Inoue, A, Freeman, M. A. R., Vernon-Ro[illegible] B & Mizuno, S (1976) The pathogenes[illegible] Perthes' disease *J Bone Jt Surg* [illegible] 453–461

Jensen, O M & Lauritzen J (1976) Legg-C[illegible] Perthes' disease. *J Bone Jt Surg* [illegible] 332–338

Jonsater, S (1953) Coxa plana. *Acta or[illegible] scand* Suppl 12, 1–99

Katz, J F (1965) 'Abortive Legg-Calvé-P[illegible] disease or developmental variation [illegible] epiphyseogenesis of the upper femur *J Sinai Hosp* 32, 651–659

Korvald, E & Sundsfjord A J (1974) Exa[illegible] tion of the vascular disturbance of the fe[illegible] head following intracapsular fracture of hip *Acta orthop scand.* 45, 572–578.

L[illegible]

L[illegible] *Acta orthop scand* Suppl [illegible]

Meyer, J (1964) Dysplasia epiphysealis c[illegible] femoris *Acta orthop scand* 34, 183–197

McKibbin, B & Ráliš, Z (1974) Pathol[illegible] changes in a case of Perthes' disease. *J B[illegible] Jt Surg* 56-B, 438–447

Rodegerdts U (1969) Aseptiche Huftkopfne[illegible] im Kindesalter nach Cortison – La[illegible] therapie bei Colitis ulcerosa. *Z Orthop* [illegible] 593–599

Sanchis M, Zahir A & Freeman, M [illegible] (1973) The experimental simulation of Pe[illegible] disease by consecutive interruption of [illegible] blood supply to the capital femoral epiphys[illegible] the puppy *J Bone Jt Surg* 55 A, 33[illegible]

Siegel, B A, Donovan R L, Alderson, P O [illegible] Mack G R (1976) Skeletal uptake of [illegible] diphosphate in relation to local bone bl[illegible] flow *Radiology* 120, 121–123

Spock, A (1959) Transient synovitis of the [illegible] joint in children. *Pediatrics* 24, 1042–104[illegible]

Sundt H (1949) Malum coxae Calvé-Leg[illegible] Perthes *Acta chir scand* Suppl [illegible] 1–101

Tucker, F R (1950) The use of radio[illegible] phosphorus in the diagnosis of avasc[illegible] necrosis of the femoral head. *J Bone J[illegible]* 32-B, 100–107

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-MIPELVECTOMY

Postoperative Rehabilitation Assessed on the Basis of 41 Cases

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Rehabilitation was evaluated on the basis of 41 consecutive hemipelvectomies for malignant tumours. Owing to early metastasization and death, 11 patients were not supplied with prostheses, while prosthetic fitting was attempted in the remaining 30 Of this number, 27 completed prosthetic training, with the result that 15 used their prosthesis, while 12 discarded it after some time, six because of poor general health owing to recurrence of the tumours and six because they felt that the prosthesis was too heavy and difficult to wear Twenty three returned to work After elimination of the most severely tumour-affected patients, there were 19 one-year survivors without recurrence Thirteen of them were using their prosthesis every day, and thirteen had gone back to work Serious mental sequelae were found in five patients, including four with long-lasting exogenous depressions and one with anxiety neurosis.

Key words hemipelvectomy, malignant tumours, prosthesis fitting rehabilitation

Accepted 1 xi 77

-mipelvectomy has been well described h respect to indications, surgical techni-s and survival (Gordon-Taylor et al. 1952, -k & Miller 1964, Ravitch & Wilson 1964, gınbothom et al 1966, Miller 1974) On the -ter hand, the literature published so far has -e little to elucidate the course of -stoperative rehabilitation, and the results -en have not been consistent Rather poor -ults were obtained by Lewis & Bickel -957) who could report only two users of the -sthesis among 25 survivors, by -ginbothom et al (1966) with 24 users -ong 60 survivors, and by Douglas et al -975) who concluded, on the basis of 50 -mipelvectomies, that the prosthesis was -metic rather than functional and that it was accepted by only a few patients. Better results were found by Miller (1959) who had 22 users out of 32 hemipelvectomized patients and the same number working and by Watkins (1962) who had 8 users a- -- 10 survivors and 6 back in employment

On this basis we felt it would be of interest to investigate the rehabilitation of hemipelvectomized patients, including especially their use of the prosthesis and their occupational rehabilitation

PATIENTS

In the Department of Orthopaedic Surgery U, Rigshospitalet, and Department I Orthopaedic Hospital, Copenhagen, 41 patients were subjected

Table 1 Histological classification

Type of tumour	No of cases
Osteogenic sarcoma	12
Chondrosarcoma	8
Osteoclastoma	3
Fibrosarcoma	6
Neurofibrosarcoma	3
Rhabdomyosarcoma	2
Synovial sarcoma	2
Myxosarcoma	3
Anaplastic sarcoma	1
Metastasis from cervical adenocarcinoma	1
Total	41

to hemipelvectomy during the period 1952 to 1976 Twenty-five of these operations were carried out during the period 1967–1976, a decade during which this treatment was centralized in these hospitals and they served an area with a population of about 2 5 million This corresponds to a frequency of hemipelvectomy of 1 in 1 million of the population *per annum* The sex ratio was 19 males and 22 females, age range 7 weeks to 79 years, mean 42 years The indication was pelvic or juxtapelvic malignant tumours, including tumours of the upper part of the thigh Table 1 lists the histological classification of the tumours.

The surgical technique was that recommended by King & Steelquist (1943), but often had to be modified in accordance with the regional extent of tumour In 29 patients it was possible to preserve the gluteal muscles. At the time of surgery 35 operations were considered radical, while in 6 macroscopic tumour tissue had to be left behind No patient died during the operation or during the first postoperative month

As for primary postoperative complications there were 13 cases of wound infection, 11 of cutaneous necrosis 3 of transient sphincter disturbances, and 21 patients had phantom pain requiring analgesic medication In 18, however the pain disappeared completely or partially, within 3 months but 3 patients went on having pain of a more permanent nature

After the operation all patients were followed regularly until death or until the present status (March 1977) For the survivors the follow-up period from the time of the operation averaged 6½ years, ranging from 6 months to 19 years 6 months, for the deceased patients 20 months, ranging from 2 months to 7 years. Local recurrence occurred in 9 patients 2 months to 3 years 6 months (mean 13 months) after the operation, and pulmonary metastases developed in 11

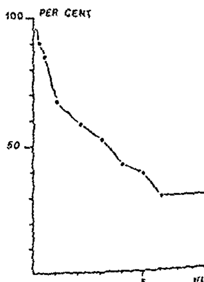


Figure 1 Survival among the 41 hemp... tomized patients during the first decade ... from the operation Survival computed ... the standard life table method.

patients from 0 months to 3 years 6 months ... 9 months) after the operation At the time ... present analysis 16 were alive and 25 had died ... from the tumour and 3 from other causes ... 1 illustrates the survival

REHABILITATION

In principle, an attempt was made to ... the patients with a prosthesis. However ... course after operation was to a great ... influenced by the underlying ... disease, many patients developing metastases ... and succumbing within the first year ... 1) Therefore, no prosthesis was made ... patients The first 6 of the remaining ... patients were primarily supplied with ... hemipelvectomy prosthesis with ... bucket-type socket and hip lock, whereas ... remaining 24 were primarily supplied ... the Canadian hip exarticulation prosthesis ... modified for hemipelvectomy (Hampton ... McQuirk 1969). Three of the 30 patients ... whom a prosthesis had been made ... unable to carry through the training ... gramme, two of them because of ... metastasization and one because of ...

ession. Of the remaining 27 fitted with a thesis, 12 later discarded it, 6 because of general health due to recurrence and 6 use of fitting problems or because they felt prosthesis was too heavy and difficult to Thus, only 15 patients wore their pros-es regularly up until the time of analysis atil they died

ccupational rehabilitation too was enced by the underlying malignant ise Nine died before rehabilitation 23 t back to work, and 9 were awarded dis ment pension.

ight patients had mental problems in the i of anxiety neurosis or depression In five of them the mental trouble was long lasting Thus, four women aged 50–53 had episodes of depression requiring treatment and lasting for 1 year or longer One of them committed suicide 6 years 6 months after the operation A 35 year-old man had long lasting anxiety neurosis which led to morphine addiction

By considering only patients who survived without recurrence for 1 year or longer, thus leaving out the most malignant cases, a better basis for assessing the consequences of hemipelvectomy as such is obtained For this assessment we have 19 patients whose use of the prosthesis and occupational rehabilitation are shown in Table 2 It will be seen that 13

le 2 Prosthetic and rehabilitation status of patients surviving without recurrence for 1 year or longer after hemipelvectomy

Sex	Age at op	Occupation before	Occupation after	Using prosthesis
F	23	clerk	clerk (part time)	daily
F	49	shop assistant	shop assistant (part time)	daily
M	42	teacher	teacher (full time)	never
M	12	schoolboy	bicycle mechanic (full time)	daily
M	26	electrician	radio mechanic (full time)	daily
M	35	shopkeeper	shop assistant (full time)	daily
M	19	bricklayer's apprentice	engineer (full time)	daily
F	68	old age pensioner	old age pensioner	daily
F	53	shop assistant	clerk (part time)	daily
M	7 wks.	—	—	daily
F	50	housewife	disablement pensioner	never
F	52	housewife	disablement pensioner	never
F	53	housekeeper	disablement pensioner	never
M	57	civil servant	disablement pensioner	never
M	30	ship builder	optical draughtsman (full time)	never
F	55	music teacher	music teacher (full time)	daily
M	37	counterman	clerk (full time)	daily
M	39	clerk	clerk (full time)	daily
F	49	housewife	housewife (full time)	daily

were using their prosthesis daily and 6 not at all It is apparent also that out of 17 who had been working prior to the operation only 9 had been able to go back to full-time work, while 4 were working part-time and 4 had been awarded disablement pension One of these 19 patients (Case 1 in Table 2) had *been through a normal pregnancy and had a* normal delivery 18 months after the operation

DISCUSSION

Like Murdoch (*1969*), we found a frequency of hemipelvectomy of 1 in 1 million of the population *per annum* The operation is indicated almost exclusively for malignant tumours, most often sarcomas Therefore the postoperative course is in general characterized far more by the underlying malignant disease than by the surgical procedure as such This makes it difficult to assess the consequences of hemipelvectomy for the patients' rehabilitation and explains the large number of patients not supplied with prostheses and not rehabilitated, also in recent publications (Higinbotham et al 1966, 1971, Wittig & Wirbatz 1971, Jones 1974) It also explains the tendency of many surgeons to consider the problems relating to the rehabilitation of hemipelvectomized patients as being fairly subordinate and in all essentials solved

However, our findings – that among tumour-free 1-year survivors about one-third of those supplied with a prosthesis later give up using it (Table 2) – reflects the appreciable difficulties involved in the wearing of a hemipelvectomy prosthesis as a rule because the patients feel it is too heavy and unwieldy and occasionally because of fitting problems The latter applies particularly to patients whose body weight fluctuates

Our material also illustrates the problems in occupational rehabilitation Half the tumour-free survivors had been unable to go back to full-time work (Table 2) Mental sequelae were somewhat more comm[...] more severe in women Like Enneking (1[...] we believe that the cosmetic result o[...] mutilating procedure is of more conc[...] women than to men

Thus rehabilitation of hemipelvecto[...] patients is still a process in which the[...] *many losers, and thereby a process* [...] constitutes a challenge not only to [...] patients and their relatives, but also t[...] therapeutic team in charge of pros[...] fitting, training and occupational rehab[...] tion

REFERENCES

Douglas H O Razack M & Holyok [...] (1975) Hemipelvectomy *Arch Surg* [...] 82–85

Enneking W F (1966) Local resectio[...] malignant lesions of the hip and pelvis *J* [...] *Jt Surg* 48 A 991–1007

Gordon Taylor G Wiles, P Patey D[...] Warwick, W T & Monro R. S. (195[...] interinnomino-abdominal operation. Ob[...] tions on a series of fifty cases. *J Bone J*[...] 34 B, 14–21

Hampton F (1964) A hemipelvectomy pros[...] *Artif Limbs* 8 3–27

Higinbotham N L Marcove R. C. & Cas[...] (1966) *Hemipelvectomy A clinical stu[...]* 100 cases with five years follow-up o[...] patients *Surgery* 59 706–708

Hogshead H P (1971) Experience with [...] articulation and hemipelvectomy proce[...] *Bone Jt Surg* 53 A 1031

Jones P (1974) Hindquarter amputation: [...] of a personal series. *Aust N.Z J Su[...]* 1–11

King D & Steelquist J (1943) Tra[...] amputation *J Bone Jt Surg* 25 351 [...]

Lewis, R C & Bickel W H (1957) He[...] tomy for malignant disease *J Amer Med*[...] 165 8–12

McQuirk A W (1969) The Canadian h[...] articulation prosthesis and modific[...] required for the hemipelvectomy In *Pro[...]* *and orthotic practice* Ed. Murdoch, G [...] 305–311 Edward Arnold Ltd., London

Miller, T R (1959) Interilio-abdominal a[...] tion A report of 32 cases *Acta* [...] *(Stockh)* Suppl 188 173–189

Miller T R (1974) 100 cases of hem[...] A personal experience. *Surg Clin N Amer* [...] 905–913

rdoch, G (1969) *Prosthetic and orthotic practice* Ed. Murdoch, G p 313 Edward Arnold Ltd., London.

k, G T & Miller, T R (1964) Exarticulation the innominate bone and corresponding ower extremity (hemipelvectomy) for primary and metastatic cancer A report of one hundred and one cases with analysis of the end results. *J Bone Jt Surg* 46-A, 91–95

Ravitch, M M. & Wilson, T C. (1964) Long-term results of hemipelvectomy *Ann Surg* 159 667–682.

Watkins, A L. (1962) Rehabilitation after hemipelvectomy *J Amer med Ass* 181, 793–794

Wittig, G & Wirbatz, W (1971) Die Hemipelvektomie, ihre Indikation, Technik und prothetische Versorgung *Dtsch. Gesundh.-Wes* 26, 857–861

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IMPACTED FRACTURES OF THE FEMORAL NECK TREATED BY EARLY MOBILIZATION AND WEIGHT-BEARING

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Among 280 patients with femoral neck fractures 46 were classi- having impacted fractures according to the criteria mentioned below treatment of patients with impacted femoral neck fractures was deter- to be mobilization with partial weight bearing from the first day of a sion Among the 42 patients successful in immediate mobilization were eight whose fractures disimpacted Three cases of avascular ne- were recorded but no cases of non union In order to determine the dictive signs of secondary dislocation the X ray findings were subjec- statistical analysis. The inclination of the fracture line dislocation valgus or varus position and the presence of retroversion did not af- the tendency to disimpaction. More than 80 per cent of the fractures without disimpaction

Key words femoral neck fracture impacted stable abduction

Accepted 18 xi 77

PATIENTS

In the period March 1971 to April 1975, a total of 280 patients were admitted to the Gentofte County Hospital, Department of Orthopaedic Surgery T 2, for treatment of fractures of the femoral neck All patients with subcapital and midcervical fractures with good contact between the fracture ends were accepted for non-operative treatment if they fulfilled the single clinical criterion of being able to raise the straight leg in the supine position According to these criteria 46 patients had impacted fractures. This study was performed to examine the effect of immediate mobilization and weight bearing in conjunction with non-operative treatment Four patients who could not be mobilized within 2 weeks of admission due to debility were therefore excluded. Thus the study comprises 42 patients Age and sex distribution are shown in Figure 1

TREATMENT

The patients were treated with immediate mobilization with partial weight bearing on two crutches. In debile patients full weight-be- was allowed During the first 6 weeks fr- radiographic examinations were perform- check for possible secondary dislocat- secondary dislocation leading to instabil- pain occurred the patients were oper- treated according to the usual principles of department.

METHODS

Anterio-posterior X rays were studied determine the inclination of the fracture line determine the inclination of the femoral femoral neck and the rotation of the femoral into a valgus or varus position was observed technique is illustrated in Figure 2, and the r- are shown in Table 1 Lateral X-rays were st- to register the presence of anteversion or ret- sion of the femoral head. The fractures w- divided into three groups anteverted, neutral retroverted The results are shown in Table 1 attempts were made to determine if the fra- were radiographically impacted.

he age and sex of the patients and type of ration performed are presented in Table 1

hnique of anaesthesia

bout 1 hour prior to the induction of the sthesia each patient received atropine 0 25 mg diazepam 5 to 10 mg i m. Anaesthesia was uced by intravenous administration of itrazepam (0 008 to 0 03 mg/kg) + fentanyl 25 to 0 05 mg/kg) + pancuronium (0 1 mg/kg) patients were intubated and normoventilated O_2 34–42 Torr, pO_2 110–180 Torr) esthesia was maintained with O_2/N_2O –2/3 v/v) and small doses of fentanyl and curonium were given intravenously when essary Compensation for blood loss by whole d was accurate throughout the operation

Measurements

Venous blood was collected with a venous catheter inserted into the vena cava superior via the vena jugularis interna The samples were immediately refrigerated in ice, centrifuged at 4°C and frozen at −40°C, until assayed Haemolytic complement (C H50) was titrated with a Technicon Auto-analyser as described by Vargues & Tagnon (1967) Results are expressed in Units/ml (normal range 300–600 U/ml) The serum concentration in C3 and C4 was measured by an immunoprecipitation technique using a [illegible]

An arterial catheter was place l in the radial artery in order to measure the arterial O_2 [illegible]

Table 1 Distribution of age, sex and type of operation

Type of operation	Total	Sex M	Sex F	Age*
tal hip arthroplasty	11	2	9	[illegible]
n-cemented hemi arthroplasty	7	1	6	[illegible]
nented hemi arthroplasty	7	–	7	[illegible]
tal	25	3	22	[illegible]

lean age in years ± S D

le 2 Sampling times during total hip arthroplasty (THA) non cement[illegible] and cemented hemi arthroplasty (CHP)

Sampling time	Arterial [illegible] THA	Arterial [illegible] [illegible]	Venous [illegible] THA	Venous [illegible] [illegible] CHP
Start of anaesthesia	+	+	+	+
Hip dislocation	+	+	+	+
1 min after the introduction of the cement into the acetabulum			+	
10 min after Step 3			+	
Before introduction of the cement and/or the prosthesis into the femur	+	+	+	
1 min after the introduction of the cement and/or the prosthesis into the femur			+	
10 min after Step 6	+	+	+	
20 min after Step 6			+	
30 min after Step 6			+	

centration (PaO_2) the arterial CO_2 concentration ($PaCO_2$) and to monitor the blood pressure (BP) and pulse continuously (EMT 34 Elema transducer + Mingograf 81 recorder). PaO_2 and $PaCO_2$ were measured directly by means of membrane electrodes (macrotechnique ILPO2–20335, ILPCO2–20334 Instrumentation Laboratory 313)

The timing of arterial and venous samplings and the operative events are indicated in Table 2

RESULTS

C'H50, C3 and C4 variations during total hip replacement, Moore arthroplasty without MMC and with MMC (Figures 1–5)

The modifications of C'H50, C3 and C4 can be related to the two phases of the procedure

Phase I Induction of the anaesthesia (samples 1, 2) The serum concentrations of C'H50, C3 and C4 were significantly decreased after the induction of the anaesthesia The effect extended slightly into the first stage of the operation

Phase II Surgery (samples 3 to 9) During surgery we observed a stabilization of C'H50, C3 and C4 During total hip surgery there was a slight but not significant decrease of C H50 after the introduction of ... and the prosthesis into the femur samples 6, 7).

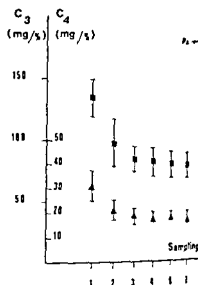


Figure 2 Variations of components 3 (C... (C4) during total hip replacement (THA)

Blood pressure and pulse (Table 3)

No modification of blood pressure were recorded during cementing acetabulum with MMC. After the ... the femoral prosthesis a decrease ...

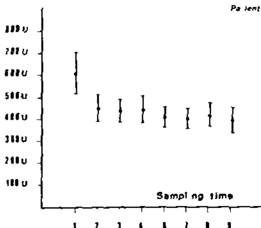


Figure 1 Variations of total haemolytic complement (C'H50) during total hip replacement (THA)

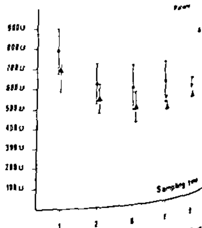


Figure 3 Variations of total ... complement (C H50) during cemented ... and non-cemented ... arthroplasty (CHP) and ... arthroplasty (NCHP)

3 *Blood pressure changes after introduction of the cement and/or the prosthesis into the femur*

pe of operation	Total	Blood pressure				
		Elevation		Drop		Minor change
		>20%	>10%	>20%	>10%	
hip arthroplasty	11	1	2	3	1	4 (36 4%)
nted hemi arthroplasty	7	–	2	1	–	4 (57%)
cemented hemi arthroplasty	7	–	–	1	–	6 (86%)
l	25	1 (4%)	4 (16%)	5 (20%)	1 (4%)	14 (56%)

ure equal to or greater than 20 per cent bserved in five patients (20 per cent) In tients (56 per cent) the variation was less 10 per cent. After impaction of the al prosthesis we noted an increase in the greater than 20 per cent in one patient (4 nt) and a decrease of more than 20 per n three patients (12 per cent)

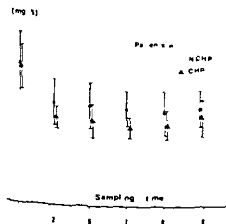
and $PaCO_2$ variations

n minutes after fixation of the femoral esis a decrease in PaO_2 of more than 10 nt was registered in eight patients (32 per cent) and an increase in $PaCO_2$ greater than 10 per cent was noted in five patients (20 per cent)

DISCUSSION

The possibility of an abnormal sensitivity to MMM during orthopaedic surgery has been suggested by Kepes et al. (1972) who observed sudden death just after fixation of the femoral prosthesis with MMC

Neither the surgery nor the introduction of the MMC affected the complement system in



4 *Variations of component 3 (C3) during ed hemi-arthroplasty (CHP) and non ed hemi-arthroplasty (NCHP)*

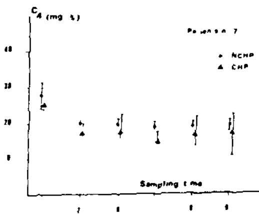


Figure 5 Variations of component 4 (C4) during cemented hemi-arthroplasty (CHP) and non cemented hemi-arthroplasty (NCHP)

the 25 patients undergoing hip surgery After recording a significant decrease of C'H50, C3 and C4 serum concentrations during the induction of the anaesthesia, we noted a stabilization of the CS during the surgical procedure This emphasizes the importance of the interaction and the method of administration of the anaesthetic drugs on the CS No relation could be found between the cardiovascular reactions and the CS variations observed In our series 20 per cent of the patients presented a BP decrease in excess of 20 per cent Parallel to this BP decrease no drop in the C'H50, C3 and C4 serum concentrations was recorded Furthermore, the CS showed no significant changes during Moore arthroplasty with (CHP) or without (NCHP) the use of MMC

The minor, statistically insignificant diminution of the CS components registered throughout the operation could be attributed exclusively to the effect of anaesthesia (repeated injections of drugs, plasma substitutes and transfusion) Haemodilution is not responsible for the initial drop of C'H50, C3 and C4 serum concentrations because all the patients received about 200 cm^3 of 5 per cent glucose solution during the induction of the anaesthesia which represents less than 5 per cent of the blood volume The reduction of the serum concentration in C'H50, C3 and C4 observed in the induction phase results very likely from an activation of the complement system Indeed this observation cannot be explained by a haemodilution (as explained above) nor by a non-specific hypercatabolism

CONCLUSION

The study of the complement system during endoprosthesis fixation with methylmethacrylate cement allows two conclusions to be drawn

1 After an important activation of the complement system during the induction of the anaesthesia with flunitrazepam, fentanyl and pancuronium, surgery does not modify the complement significantly

2 The introduction of the cement does [illegible] induce an activation of the complement [illegible] an immunological process [illegible] involved in some of the cardiovasc[illegible] phenomena occurring during [illegible] arthroplasty MMC is not responsible for [illegible] activation of the complement system

ACKNOWLEDGEMENTS

We wish to thank the Orthopaedic Dep[illegible] (Prof de Marneffe) of the Brugmann [illegible] Hospital for allowing us to study patients [illegible] their care

REFERENCES

Berman, A T, Price, H L & Hahn, J F [illegible] The cardiovascular effects of methyl[illegible] acrylate in dogs *Clin Orthop* 100, 26[illegible]

Cadle, D, James, W L, Ling R S M, [illegible] R F & Wilmshurst C C (197[illegible]) C[illegible] spondence *Brit med J* 4, 107–108

Carson, C, Gorman, J M & Becker E [illegible] Technicon Symposia Automated [illegible] munoprecipitin system for proteins in [illegible] fluid Further advances, p 36 Medi[illegible] White Plains, N Y

Charnley, J (1970) *Acrylic cement in ortho[illegible] surgery* Livingstone, Edinburgh & London

Cohen C A & Smith, T C (1971) The [illegible] operative hazard of acrylic bone cement [illegible] of a case *Anesthesiology* 35, 547–549

Deichmann W (1941) Toxicity of methyl [illegible] and N butyl methacrylate *J industr Hyg* [illegible] 343–351

Deutman, R (1974) *Experience* [illegible] *McKee–Farrar total hip arthroplasty* [illegible] Gorcum & Co. B V Assen, The Netherlands

d Hollander, A., Burny, F., Moreau [illegible] Donkerwolcke, M (1976) Ex[illegible] variations of temperature during polymeriz[illegible] of acrylic cement in hip arthroplasty [illegible] *orthop scand* 47, 186–188

Fearn B, Burbidge, H C & Bentley G [illegible] The effect of methylmethacrylate cement [illegible] blood pressure *Acta orthop scand* [illegible] 318–324

Frost, P M (1970) Correspondence *Brit med* [illegible] 3, 524

Hausberger, P X & Whitenack, S H (19[illegible]) [illegible] of pressure on intravasation of fat from the [illegible] marrow cavity *Surg Gynec Obstet* [illegible] 931–936

sy C. A. (1969) *Prosthesis seating compounds rapid cure acrylic polymer* Joint workshop ı total hip replacement and skeletal tachment. National Academy of Science nerican Academy of Orthopaedic Surgeons.

s, E D Underwood, P S & Becsey, L 972) Intraoperative death associated with rylic bone cement *J Amer med Ass* **222**, '6–577

er J A. (1916) Studies in non specific mplement fixation The influence of lenectomy and anesthetics on non specific mplement fixation sometimes shown by rmal rabbit and dog sera. *J Infect Dis* **18**, –45

R S M. & James, M L (1971) Blood essure and bone cement *Brit med J* **2**, 404

ieu, A (1976) Action de l anesthésie générale r le complément. *Ann. Anesth franç* **17**, 5–257

aster W C, Bradley, G & Waugh, T R. 974) Blood pressure lowering effect of methyl-ethacrylate monomer Potentiation by blood lume deficit. *Clin. Orthop* **98**, 254–257

, I S (1973) Hazards of acrylic bone cement *naesthesia* **28**, 538–543

g J, Olerud, S & Malmberg P (1973) idden pulmonary dysfunction in prosthetic hip placement surgery *Acta anaesth scand* **17**, 6–282.

eny E, Jaspar, N & Dubois-Primo, J (1975) ôle possible du méthacrylate de méthyle dans les accidents cardiovasculaires observés en chirurgie orthopédique *Anesth Analg Réanim* **32**, 119–124

Ohnsorge, J (1971) Some aspects of polymerising bone cement. *J Bone Jt Surg* **53-B**, 758

Pasteyer, J, Jean, N & Guery, J (1976) Inefficacité circulatoire peropératoire par hypothermie au cours des transfusions massives. 25me Congrès National Français d'Anesthésie-Réanimation. Vittel Mai 1976

Peebles, D J, Ellis, R H, Stride S D K. & Simpson, B R. (1972) Cardiovascular effects of methylmethacrylate cement *Brit med J* **1**, 349 351

Pelling, D & Butterworth, K R (1973) Cardiovascular effects of acrylic bone cement in rabbits and cats. *Brit med. J* **2**, 638–641

Phillips, H., Cole, P V & Lettin, A. W (1971) Cardiovascular effects of implanted acrylic bone cement *Brit med J* **3**, 460–461

Sevitt, S (1972) Fat embolism in patients with fractured hip *Brit med J* **2**, 257–262.

Vargues R. & Tagnon A (1967) Technicon Symposia Dosage du complément des sérums humains avec l'auto-analyser Technicon, p 25 Media Inc., White Plains, N Y

Wagner, J, Burny F., Geens J de Marneffe R & Blaimont P (1969) Etudes cliniques et expérimentales sur l action hypotensive du plastique acrylique SICOT, XI Congrès, Mexico October 1969

spondence to Dr E Monteny 42 Rue Van Rolleghem B–1090–Brussels, Belgium.

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EXPERIENCES WITH TOTAL HIP REPLACEMENT ARTHROPLASTY *AD MODUM* RING

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The results of total replacement of the hip joint *ad modum* Ring [illegible] sented The review includes 63 hips (from among the total number [illegible] operated by the various methods) followed up for periods ranging [illegible] [illegible] excellent results in [illegible]

Key words Ring total hip prosthesis hip joint

Accepted 5 x 77

Total replacements of the hip joint *ad modum* Ring (Ring 1968, 1970, 1971, 1973, 1974) have been performed at the Orthopaedic Hospital, Medical Faculty, University of Zagreb, since 1970 It was decided to use Ring's prosthesis, because it seemed well [illegible] biomechanically and did not involve the use of cement It should be emphasized that the indications for total replacement of the hip joint have been extremely conservative It has been used only in cases when no other type of surgery could be expected to offer better results with regard to the local alterations in the hip joint, the patient's age and profession

PATIENTS AND METHODS

Sixty-three operations on 59 patients were carried out (Table I)

The disorders causing the hip alterations are shown in Table 2 and the age distribution of the patients (the majority were between 60 and 70) is given in Figure 1

The assessment of the results is based on the usual three main factors stability of the hip during walking pain, and range of movement (modified from the evaluation of results [illegible] Ring)

Excellent results in this evaluation [illegible] completely stable and painless hips with [illegible] of flexion over 90° and corresponding [illegible] adduction and rotation.

Table 1 Sex and side distribution

	Right	Left	Bilateral	T[illegible]
Female	19	21	2	[illegible]
Male	7	12	2	[illegible]
Total	26 41.3%	33 52.3%	4 6.4%	[illegible]

Table 2 Hip disorders

	Number of hips	Per[illegible]
Osteoarthritis	44	[illegible]
Congenital dislocation	7	[illegible]
Rheumatoid arthritis	4	[illegible]
Ankylosing spondylitis	4	[illegible]
Femoral head necrosis	3	[illegible]
Injury	1	[illegible]
Total	63	[illegible]

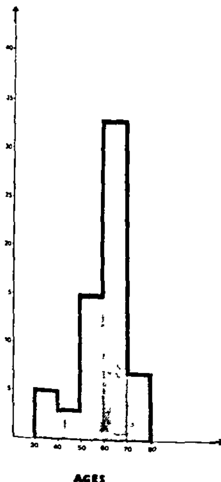


Figure 1 Age distribution

results included those patients who
es had to use one stick when walking and
ermittent moderate pain or continuous
ain. The flexion of the hip was between
d 90° while other movements were
at restricted.
results included patients who had to use a
a short crutch and had moderate pain all
e and whose flexion ranged between 30°
°, while their other movements were
d.
results included those patients who were
to walk without crutches, had constant and
ain, and their range of all hip movements
r, flexion being less than 30°
patients have been checked at 3- to 6-
intervals after the operation, and the
on includes the follow-up examinations
out 6 months to 5 years after the operation
3).

Table 3 Period of review

Years	Number of hips	Percentage
1/2–2	17	26 9
2–3	20	31 8
3–4	6	9 5
4–5	20	31 8
Total	63	100

RESULTS

The results of the operations graded according to the above evaluation are shown in Table 4

Complications

There were no complications at surgery, there was no dislocation of the prosthesis, bone fracture, or lesion of the sciatic nerve

Among late complications there were three cases of instability of the prosthesis as a result of infection and two patients developed loosening of the prosthesis without evidence of infection The prosthesis had to be removed in the three cases of infection because of functional and subjective complaints. Arthrodesis was carried out in one case and a Girdlestone operation in two cases.

In order to prevent infection Keflin has been administered according to an agreed schedule, since 1973, i e, in the 24 most recent cases. None of these developed infection Anticoagulants have been given in all cases with previous thrombosis or with

Table 4 Results

Grading	Number of hips	Percentage
Excellent	21	33.3
Good	32	50 8
Fair	6	9 5
Poor	4	6 4
Total	63	100

marked varicose veins of the lower extremities

Migration of the prosthesis occurred in one case of infection and in one case of bilateral replacement where the patient had ankylosing spondylitis. In some cases a radiolucent zone around the acetabular stem of the prosthesis was noticed This zone, about 1 mm in diameter, was surrounded by denser bone and *is probably a layer of fibrous tissue This so-*called halo effect was not linked with subjective symptoms in the majority of cases Para-articular calcifications when present did not cause subjective complaints either, but the range of movement was somewhat restricted

DISCUSSION

In the authors' experience preliminary results of the application of Ring's prosthesis were satisfactory provided the indications for the operation were strictly adhered to and the operative technique was of a high standard

As in all other total replacements of the hip joint performed in this hospital i e, *ad modum* McKee-Farrar and St. George, the have been very conservative 's prosthesis has been applied mainly in patients without marked osteoporosis who were expected to perform heavy work post-operatively

As regards the surgical technique, [illegible] be added that it is more difficult to [illegible] than other methods of total [illegible] the hip particularly as regards the [illegible] of the acetabular part of the [illegible] altered position and shape of the [illegible] could present difficulties in [illegible] cially when inserting the stem of the [illegible] component In our opinion full [illegible] bearing should not be introduced until [illegible] months *after* surgery In most cases [illegible] earlier weight bearing signs of [illegible] stability with a positive [illegible] Trendelenburg's symptom occurred [illegible] was regarded as an undesirable [illegible] the reflexive unburdening of the hip

We have noticed that the results [illegible] deteriorate in the course of time.

REFERENCES

Ring P A (1968) Complete [illegible] arthroplasty of the hip by the Ring [illegible] *J Bone Jt Surg* 50 B 720–731

Ring P A (1970) Replacement of the hip [illegible] *Orthop* 72 161–169

Ring P A (1971) Replacement of the [illegible] *Ann roy Coll Surg Engl.* 48 344–[illegible]

Ring P A (1973) Total replacement of the [illegible] joint *Clin Orthop* 95 34–37

Ring P A (1974) Total replacement of the [illegible] joint *J Bone Jt Surg* 56-B 44–[illegible]

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thop. scand. 49 195–204, 1978

MONSTRATION OF ROTATORY INSTABILITY INJURED KNEES BY STRESS RADIOGRAPHY

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tment of Orthopaedic Surgery T–3 and Department of Diagnostic Radiology, ientofte Hospital, Copenhagen, Denmark.

Rotatory instability of injured knees may be demonstrated by stress radiography by recording the different movements of the medial and lateral tibial condyle at pull or push with the knee in 90 degrees flexion. The displacements of the condyles are expressed in millimetres, not degrees. Comparison with the healthy knee is always used. The displacement of a tibial condyle has to exceed 3.0 mm in relation to the healthy knee to be defined as pathological. If the movements of both condyles exceed the movements in the healthy knee by more than 3.0 mm in the same direction a drawer sign is present – if only one of them moves, an abnormal rotation is present. When a drawer sign is present there may still be a greater displacement of one of the tibial condyles which means a rotatory instability added to the drawer sign, designated a complex rotatory instability. All types of rotatory instabilities, simple and complex, are defined and discussed, in relation to the classification of Nicholas, Trickey and Slocum & Larson. Forty-one cases of abnormal rotation were demonstrated in this series by stress radiography. The direction of rotation and the type of instability are described and compared with the operative findings. The findings are in agreement with those of the above-mentioned authors and the experimental work of Warren et al.

Key words: complex instability, gonylaxometry, knee rotatory instability, complex, simple, stress radiography

Accepted 12.x.77

(1853) was the first to measure the n in healthy knee joints of living human s. The measurements were made at nt degrees of knee flexion, using a ruler n the sole of the foot, the ankle joint immobilized by a tight bandage. Ross in 32 published a thorough study of 100 ojects with healthy knee joints, also using an ernally placed ruler and measuring in grees. Ouellet et al. (1969) have suggested a thod for investigation of rotatory stability 90° flexed knee joints by means of measurements on serial radiographs. In this method the measured distances on the radiographs are transformed (by a cosine relationship) to degrees of rotation. As this method presumes a knowledge of the centre of rotation, only an approximate calculation is possible and furthermore it is only practicable in the healthy knee, while in the injured knee, in which the centre shifts to an unknown position, it is of no value. So far there have been no publications of measurements of rotation in injured knee joints. It is the

marked varicose veins of the lower extremities.

Migration of the prosthesis occurred in one case of infection and in one case of bilateral replacement where the patient had ankylosing spondylitis In some cases a radiolucent zone around the acetabular stem of the prosthesis was noticed This zone, about 1 mm in diameter, was surrounded by denser bone and is probably a layer of fibrous tissue This so-called halo effect was not linked with subjective symptoms in the majority of cases Para-articular calcifications when present did not cause subjective complaints either, but the range of movement was somewhat restricted

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REFERENCES

Ring P A (1968) Complete [illegible] arthroplasty of the hip by the Ring pr[illegible] *J Bone Jt Surg* 50-B 720–731

Ring P A (1970) Replacement of the hip [illegible] *Orthop* 72 161–169

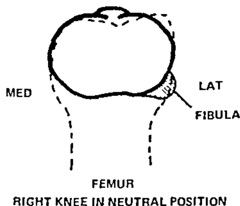
Ring P A (1971) Replacement of the hi[illegible] *Ann roy Coll. Surg Engl.* 48, 344–[illegible]

Ring P A (1973) Total replacement of [illegible] joint *Clin Orthop* 93 34–37

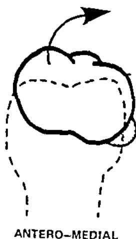
Ring P A. (1974) Total replacement of [illegible] joint *J Bone Jt Surg* 56-B 44–55

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COMPLEX ROTATORY INSTABILITY



RIGHT KNEE IN NEUTRAL POSITION



ANTERO–MEDIAL



ANTERO–LATERAL





purpose of this paper to show that gonylaxometry (Jacobsen 1976) offers a practical possibility for obtaining such measurements.

Definitions

In this paper internal and external rotation refer to the movement of the tibia in relation to the fixed femur *Internal rotation* means that the tibial tuberosity rotates medially, the posterior parts of the tibial condyles moving laterally around an axis in the direction of the tibial shaft. *External rotation* indicates the reverse movement

Medial instability (or valgus laxity) is defined as a movement in the frontal plane by which the knee joint is opened medially to a greater extent than normally The patient's uninjured knee is used for comparison In the gonylaxometer the measurement is done in 20 degrees knee flexion (angle between thigh and lower leg 160 degrees) The medial gap on the film is used as defined (Jacobsen 1976)

Lateral instability is defined analogously

Drawer signs are defined as contemporary antero-posterior displacements of both tibial condyles in relation to the respective femoral ndyles The knees are flexed 90 degrees, the pointing straight forwards and parallel to the direction of the pulling or pushing force In gonylaxometry *a certain critical level of* anterior or posterior displacement must be exceeded to establish a drawer sign as distinct *from a normal antero-posterior displacement* (a mean value exceeding 3 0 mm is used as a critical level, Jacobsen 1977)

Rotatory instability is defined in accordance with the remarks on internal or external rotation It is measured in the gonylaxometer in 90 degrees knee flexion using the same method and stress forces as when measuring drawer signs The term *simple rotatory instability* is used in circumstances where only the movement of one tibial condyle exceeds the critical level (no drawer sign present), in *complex rotatory instability* the movement of both tibial condyles exceeds the critical level but the *one moves further than the other*, which means a rotation in addition to a drawer sign The diagram *of* the [illegible] complex rotatory instability is [illegible] Figure 1 The direction of the [illegible] movement cannot be *deduced from the* [illegible] of the different types of instability [illegible] classification The names are derived [illegible] unstable *structures*. For example, [illegible] medial complex rotatory instability [illegible] name *from* the injured anterior [illegible] medial ligaments. The *direction of the* [illegible] is external From this it follows that [illegible] instabilities as well as medial, lateral [illegible] antero-posterior *instabilities are* [illegible] millimetres and *not* converted into [illegible]

METHOD

From gonylaxometry *measurements* [illegible] subjects in a neutral position it can be [illegible] when a straight pull *in the anterior* [illegible] applied to the upper end of the [illegible] displacement of the medial and lateral [illegible] condyles is *of* different amplitude. The [illegible] anterior displacement of *the* medial [illegible] 2 3 *mm* (rounded off 2 mm) in 34 subjects [illegible] the mean *for* the lateral condyle is 4 4 mm [illegible] or *nearly twice* as much as the medial condyle [illegible] means an internal rotation of the tibia as [illegible] Figure 2. When an *opposite* force is [illegible] posterior displacement in the normal [illegible] found to be *nearly twice* as much on the [illegible] condyle as on the medial (mean values 1 1 [illegible] external rotation takes place

If any *abnormal* rotation is to be [illegible] the method of *choice* is *to* compare the [illegible] parameters of the patient's healthy and [illegible] knee In the following all instabilities [illegible] are *defined* as "movement in the [illegible] minus movement in the healthy knee" The [illegible] cent *upper confidence limit* of the [illegible] between the two knees of a healthy [illegible] above-mentioned *parameters* (anterior or [illegible] displacement of each condyle) is about [illegible] ranges from 2.5 *to* 3 1 mm. *A* [illegible] 3 0 mm is chosen for practical [illegible] displacement of a *tibial* condyle has to [illegible] critical level *to* be defined pe[illegible] condyles move *beyond this* level [illegible] direction a drawer sign is present. [illegible] condyles moves enough *to exceed* this [illegible] abnormal rotation must be present. The [illegible] criteria for a positive finding *of* rotatory [illegible] are *suggested* (a) the rotating condyle [illegible] displaced minimally 3 0 *mm* and [illegible]

position with the feet fastened in 15 es external rotation it should be positive subsequent surgical operation would then ... intact cruciate ligaments intact lateral tures and injury to the medial collateral ents alone Two such cases were found in 2. Both of them showed a mean anterior acement of the tibial condyles of 4 4 mm ie position with 15 degrees external ion of the feet Furthermore in one of with 30 degrees external rotation of the there was an anterior displacement of am Thus stress radiography nstrated a positive Slocum & Larson The menisci were intact in both patients. condly simple rotatory instability may be n by stress radiographical measurements in the neutral position of the foot. In a case the medial tibial condyle at pull ing from 'neutral position 90 degrees" d 3 2 mm (criterion a) which exceeded movement of the lateral condyle by 2.1 mm rion b) which shows external rotation, e the mean of the two condylar ments (2.2 mm) did not exceed the al level of 3 0 mm for anterior drawer With the feet fastened in 15 degrees nal rotation the difference between ial and lateral condylar movement was greater Intact menisci were found at ation These three cases from group 2 had scar tissue after rupture of medial nents. A further seven simple medial tory instabilities from group 1 and two group 3 are shown in Table 1 and res 3 and 4, making a total of 12 cases. *imple lateral rotatory instability* was d in two cases.

omplex rotatory instabilities of all the s shown in Figure 1 were found in 25 s in 24 knees *antero-medial* in 19 cases ble 2). The pathoanatomy in all these cases sisted of anterior cruciate ligament rupture bined with medial collateral ligament ture This was clearly visible in group 1 less obvious in the other groups where scar ue had developed at the site of the medial ctures.

ostero-medial complex rotatory instability was demonstrated by gonylaxometry in three cases One case is shown in Figure 5 In the second case anterior drawer (7 7 mm) was found coupled with a posterior drawer (18 5 mm) and postero-medial instability at push (difference between posterior displacement of the tibial condyles 2 1 mm) Subsequent operation showed total rupture of both cruciate ligaments, the medial collateral ligaments and the capsule, as well as the postero-medial part of the capsule The third case with total rupture of the medial structures and posterior cruciate ligament showed external rotation at pull and posterior drawer sign at push.

In one case *combined antero-lateral and postero-lateral complex rotatory instability* was demonstrated. The findings at operation were Total rupture of the anterior and posterior cruciate ligament, lateral collateral ligament, popliteus and biceps femoris tendons, posterior and lateral capsule and partial rupture of the iliotibial tract and the medial collateral ligament In another case of postero-lateral complex rotatory instability the operative findings were total rupture of the posterior cruciate ligament and the lateral collateral ligament.

In six patients external rotation in the injured knee occurred in the unloaded knee during rotation of the foot from the neutral to the 15 degrees externally rotated position Only two of them were not further rotated by stress (external rotation – medial instability) The same criteria of rotation were used as in loaded knees.

Totally 41 instances of abnormal rotation in 40 knees were shown by stress radiography in the series.

DISCUSSION

Slocum & Larson (1968) describe the clinical test position "with the foot and leg in 15 degrees external rotation" This has caused some practical difficulty, as the head of the tibia rotates less than half the rotation of the foot. Nevertheless the position of 15 degrees

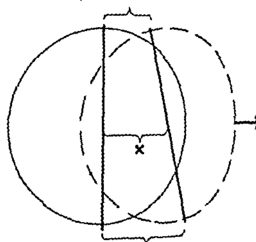


Figure 2 Tibial head (right, seen from above) diagramatically shown as a circle During application of a pulling force (arrow) the medial condyle moves less than the lateral On the radiograph straight linear distances are measured to represent the movement of each condyle The landmarks used for the measurements are on the posterior part of the circle but in the same way points on the middle of the medial and lateral sides move A chord at the posterior part of the circle, through the landmarks, will move parallel to the diameter shown and thus show the same angle of rotation. The movement of the centre shows the anterior displacement The diagram may represent a normal knee *if the braces represent the total movement in a normal knee On the other hand it may represent* complex rotatory instability, *if the braces represent differences between an injured and a healthy knee of the same patient*

condyles of the injured knee are displaced to some degree the difference between the two condyles *must exceed 2 0 mm (2 SD in healthy knees)*

If both condyles can be displaced more than 0 mm and added to this one condylar displacement exceeds the other by 2.0 mm a drawer *sign plus a rotation is present or in other words a* complex rotatory instability exists (refer to Figure 2 and its legend)

Rotatory movements were studied both in the *normal position for examination for drawer sign* 'neutral position 90 degrees" with the feet pointing straight anteriorly and *in positions* with the feet externally or internally rotated 15 degrees and 30 degrees. The fastening gear may also be fixed in these positions in the gonylaxometer

PATIENTS

The material comprises 153 injured knees, 90 were examined 2 weeks or less after the injury (group 1), 26 from 15 days to 3 months after the injury (group 2) and in 37 a period of more than 3 months had elapsed since injury (group 3) For further details of the material, the various pathoanatomical features, medial and lateral instability, drawer signs, etc. refer to Jacobsen (1977) In many cases small differences in antero-posterior displacement of the *medial* and lateral condyles of the [illegible] knee not exceeding the above [illegible] *levels*, were found radiographically [illegible] discussed further in this report. [illegible] with the *feet* in 15 and 30 degrees [illegible] mentioned above were carried out [illegible]

FINDINGS

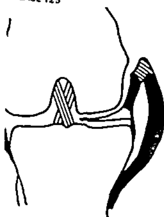
Simple rotatory instability may be [illegible] strated *in* two different ways. [illegible] of Slocum & Larson (1968) may be [illegible] with the feet *fixed* in 15 [illegible] rotation and the knees flexed to 90 [illegible] the gonylaxometer *Prior to this* [illegible] *of the lateral* collateral ligaments [illegible] by Slocum & Larson and a [illegible] stability at *stress radiography* [illegible] If an external rotation is to be [illegible] a result of *injury to the* [illegible] ligaments alone the following [illegible] fulfilled provided the *lateral* [illegible] intact an anterior drawer test [illegible] in neutral position must be [illegible]





...re 3 Operative findings in case no 1 Isolated partial rupture of the superficial medial collateral ...ment—long anterior fibres ruptured ... ...ent medial insta...

CASE 125



GONYLAXOMETRY

MEDIAL LOOSENESS 4 6 mm
ANTERO POSTERIOR DISPLACEMENTS
IN NEUTRAL POS

ANT DISPL LAT CONDYLE	1.2 mm	
ANT DISPL MED CONDYLE	3 0 mm	
POST DISPL LAT CONDYLE	0 5 mm	
POST DISPL MED CONDYLE	3 0 mm	
ANT DRAWER (2 5=neg)		
POST DRAWER (1 8=neg)		
TOTAL ANT-POST DISPL LAT COND		2 5
TOTAL ANT-POST DISPL MED COND		6 0

WITH FOOT 15° OUTW ROTATED THIS IS INCREASED TO 7 1

...ure 4 Isolated rupture of medial structures superficial and deep medial collateral as well as oblique ...terior ligament and medial capsule Simple medial rotatory instability

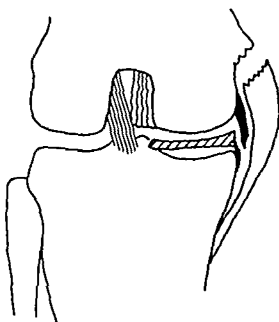


Figure 5 Recent injury Case no 89 Postero-medial complex rotatory instability (posterior d rotation)

Table 2 Examples of antero medial complex instabilities Measured in mm.

Pt no	Medial instability	Ant displ med cond		Ant displ lat cond	Difference = measure of rot	Ant. displ. (mean of med. and lat. cond)	Me… inju…
71	9 3	neutr	18 7	13 4	5 3	16 1	none
80	12 7	neutr	7 8	7 6	0 2	7 7	none
		15° ext	16 8	13 3	3 5	15 2	
84	4 8	neutr	5 4	2 2	3 2	3 8	none
		15° ext	5 9	2 8	3 1	4 4	
85	9 1	neutr	13 9	10 2	3 7	12.1	medial
115	none	neutr	3 6	0 9	2 7	2 3 (none)	both m… and lat. removed earlier
		15° ext	6 2	3 1	3 1	4 7	
116	5 9	neutr	8 4	6 3	2.1	7 4	none
		15° ext	7 9	4 9	3 0	6.4	
		30° int	3 7	2.4	1 3	3 1	
129	none	neutr	7 2	3 3	3 9	5 3	med + la…
130	none	neutr	8 5	4 4	4 1	6 5	med
133	none (1 9)	neutr	12 1	8 7	3 4	10.4	med rem… earlier

The difference between the movement of the two tibial condyles is calculated in column five … drawer in column six

·rnal rotation of the foot was chosen as a ıdard position, when examining for ıtory instability *ad modum* Slocum & ·son but in nine cases the knee was tested ı with the foot fixed in 30 degrees external ıtion (which forces the proximal end of the a closer to 15 degrees external rotation as ·asured by an externally fixed pointer) As ·ı from the first mentioned cases with ple medial rotatory instability the latter ıtion may give an even better outcome of ·› test in favour of the theory of Slocum & ·son.

n case no 78 with operatively proven ıl rupture of the medial collateral liga-·nts and the anterior cruciate ligament ‹ rotation was shown with the foot in the ··tral position, but a great increase of the erior displacement with the foot in the 15 rees externally rotated position gave ·lence of medial rotatory instability When tibial condyles are rotated externally the o-fibular insertions of the lateral structures ve posteriorly and, therefore, allow a ater anterior movement at pull even when ·ıct. This movement, prevented when the ·dial ligaments are undamaged occurs when ·y are damaged and to a still greater degree en the anterior cruciate ligament is ·tured also (still in agreement with the ory of Slocum & Larson)

Intero-medial instability was shown by ckey (personal communication 1976) on laveric knees with totally cut medial lateral ligaments and intact cruciate ments, with the knee flexed 30 degrees, as ombined medial gap and external rotation. e present author agrees with this point of w, but prefers to analyse each of these vements (gap in frontal plane and rotation) arately

In the case in Figure 4 nature has produced injury so "clear cut' that it may easily be produced experimentally on knee specimens. such a specimen Trickey demonstrated his nteromedial instability With the methods d definitions used by the present author it is possible to demonstrate both medial ·tability in the frontal plane in this case and external rotation (anterior displacement of the medial tibial condyle at 90 degrees knee flexion and pull) and internal rotation (posterior displacement of medial condyle at push) due to instability of the medial structures alone

Rotatory instability at gonylaxometry was only demonstrated in cases where operation disclosed a total rupture of the long anterior fibres of the superficial medial collateral ligament, the exact pathoanatomy being only accessible in the recent injuries and a few other cases (as in Figure 4) with non union and scanty scar tissue formation No rotation exceeding the critical levels of the criteria were shown in injuries comprising only the deep and oblique posterior medial collateral ligaments This is in agreement with Warren et al (1974, p 671 and charts IV and V) who write " relatively large increments in both medial joint space opening (valgus) and rotation are allowed by releasing the long fibres in an otherwise intact specimen Conversely, cutting the deep ligament produces almost no change if the long fibres are intact"

As the middle and posterior fibres of the superficial medial collateral ligament are taut in extension and slight flexion but slack and inverted anteriorly in 90 degrees knee flexion [refer to Lanz & Wachsmuth (1938) p 233, abb 188 or Warren et al (1974) p 666], and the anterior fibres behave in the opposite way (slack in extension and taut in 90 degrees flexion) findings like those in case no 1 (Table 1 and Figure 3) may occur The middle and posterior fibres, intact in this case, prevent medial instability, when measured in 20 degree knee flexion (the 160 degrees position) as in the gonylaxometer In the 90 degrees position in which they are slack and anteverted they allow anterior displacement of the medial tibial condyle – or external rotation This movement should have been prevented by the anterior fibres of this ligament, but they have ruptured in this case The injury was sustained in a skiing accident during flexion and external rotation of the knee The same occurred in case no 2

Complex instability was def

classified by Nicholas (1973) as contemporary instability in two or more planes Referring to this definition Trickey's antero-medial instability is a kind of complex instability The author of this article prefers to use the term complex instability only in connection with rotatory instability Within this concept the terminology is defined in full agreement with Nicholas' nomenclature Lastly attention must be drawn to the measuring technique with a force acting which tightens the intact structures The rotation produced in this way is probably less than if a rotating force were applied directly with the knee in the neutral position (no antero-posterior stress on the ligaments) Some findings indicate this In case no 150 the feet were also rotated externally 30 degrees and then tested for anterior displacement—and no movement at all of the medial condyle was found But unloaded the medial condyle had moved 7 4 mm more than the lateral from neutral position to the position with 30 degrees externally rotated feet, i e, the rotation had taken place already before the pulling force was applied to the rotated leg Such rotation of the unloaded knee was found in another five cases, but only two did not move further on

It may be concluded that rotatory instability of the knee simple, medial and lateral, as well as all the complex types discussed theoretically and the antero-medial type shown clinically by Nicholas—can be demonstrated and measured by stress radiography in a clinical material of injured knees. The findings are in agreement with the experimental work of Warren et al (1974)

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REFERENCES

Jacobsen K (1976) Stress radiogr measurement of the anteroposterior medial lateral stability of the knee joint. *Acta or scand* 47, 335–344

Jacobsen K (1977) Stress radiogr measurements of post traum c i instability A clinical study *Acta orthop s* 48, 301–310

Lanz T von & Wachsmuth, W (1938) Prak *Anatomie* Band I, Teil 4 *Bein und S* p 233, abb 188 Springer Verlag Berlin

Meyer, H (1853) Die Mechanik des Knie Arch. Anatomie Physiol. Wiss. Med (M Archiv) 497–538 pp 534–535

Nicholas J A. (1973) The Five-One Reco tion for anteromedial instability of the kn *Bone Jt Surg* 55-A, 899–922

Ouellet R. Lévesque H P & Lawren, C (The ligamentous stability of the kn experimental investigation. *Canad. M J* 100, 45–50

Ross R F (1932) A quantitative study of of the knee joint in man. *Anat. Re* 209–233

Slocum D B & Larson, R. L. (1968) Ro instability of the knee. Its pathogenesis clinical test to demonstrate its pres *Jt Surg* 50-A, 211–225

Trickey, E. L., F R C.S. (1976) munication and

Warren, L F, M The prime stat the knee. *J*

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:UDOCHONDROMALACIA PATELLAE

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A condition causing knee pain with retropatellar crepitus similar to chondromalacia patellae is described. The symptoms seem to be due not to chondromalacia of the patella, but to a local synovial thickening proximal to the articular surface of the medial femoral condyle. Thirteen patients, aged 10 to 21 years, were operated upon because of this condition, three of them bilaterally. In most of them the changed synovial membrane was excised. The operation in eleven of the knees was followed by considerable or complete relief. Of the remaining five knees, three were temporarily improved.

Key words: pseudochondromalacia patellae, chondromalacia patellae, knee joint, synovitis

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gle (1972) and Smillie (1974) have ribed a condition with knee pain caused thickening of the synovial membrane thickening was localized to the anterior oral surface just proximal to the articular ace. Both authors stress that the condition be mistaken for chondromalacia patellae gle called the condition "pseudochondro-acia of the patella". This report seems to irm Nangle's and Smillie's observations.

TIENTS

material consisted of thirteen patients, six s and seven females. Three of the females were ated upon bilaterally. The patients ages at the of operation ranged from 10 to 21 years (mean years) (Table 1). The patients presented for tment over a period of 3 years at an opaedic department serving a population of ,000 inhabitants. During the same period ndromalacia patellae was diagnosed in a much er number of cases.

Symptoms

The duration of symptoms varied between 6 months and 5 years, in most cases more than 2 years. All of the patients denied any known trauma. The condition was not related to any particular type of physical activity.

All the patients reported knee pain when walking or running. The pain was localized to the anterior part and sometimes also to the inside of the knee. The pain became more pronounced on exertion. After exertion the pain was often felt for some hours even at rest. None had any history indicating luxation or subluxation of the patella. Spontaneous pain at rest was common. Most of the patients had a feeling of crepitations in the knee and several had experienced a sensation of momentary catching but not actually locking. None had noticed any swelling of the knee. Nine had bilateral symptoms. In three of them both knees were operated upon while in the remaining six the symptoms in the other knee were not considered severe enough to warrant operation. For further details concerning the symptoms see Table 1.

None of the patients had any manifestations of generalized joint disease or other systemic illness at the time of operation. However later one of the patients developed symptoms in other joints and he might possibly have rheumatoid arthritis.

Table 1 Clinical details (thirteen patients)

	Age at operation (years)	Sex	Symptoms bilaterally	Side operated	Duration of symptoms (years)	Pain on motion	Pain at rest	Feeling of crepitations	Catching	Follow up time (years)	Postoperative results	Remarks
	10	F	+	R	1	+			+	2.5	Improved	
	13	M		R	3	+	+	+		2	Symptom free	
	13	M		R	1	+	+			3	Symptom free	Partial chondrectomy of patella
	14	M	+	R	1	+		+		2.5	Improved	
	15	F	+	R	2	+		+		2	Symptom free	
	16	F		L	2	+	+	+		1	Symptom free	
	16	M	+	L	1.5	+		+		2	Not improved	Symptom free for 4 months postoperatively
	17	F	+	L	2	+	+	+	+	1.5	Symptom free	
operated bilaterally	17	F	+	R	2	+	+	+	+	2	Improved	
	18			L	3	+	+	+	+	0.5	Improved	Partial chondrectomy of patella
operated bilaterally	18	F	+	R	4	+	+		+	2.5	Symptom free	
	19			L	5	+	+		+	1.5	Not improved	Symptom free for 3 months postoperatively
	20	M	+	R	3	+		+		2.5	Not improved	Symptom free for 4 months postoperatively
	20	M		R	0.5	+		+		2	Not improved	Rheumatoid arthritis ?
operated bilaterally	20	F	+	L	0.5	+			+	2.5	Improved	
	21			R	1	+	+	+		2	Not improved	Fracture of patella 3 weeks postoperatively

The cartilage of the proximal [illegible]

h the knee extended translation of the patella nally or distally applying simultaneous re to the upper part of the patella invariably ced painful crepitations. These crepitations ibled those which can be felt in romalacia patellae. All the knees were tender lpation in an area covering 3–4 cm^2 on the or surface of the femur, immediately proximal e articular surface of the medial femoral le (Figure 1). Palpation of this area revealed a uneven *surface*. This part of the ination was best carried out with the knee 70–80°. The stability of all the knees was al and none showed evidence of exudate. In all nees the position of the patella relative to the al condyles was judged as normal. In all the nts the mobility of the ankle, knee and hip was normal. Three patients could not squat with their heels flat on the ground.

e E.S.R. was normal in all patients. A–P genograms of the extended knee and lateral s of the knee flexed about 30° were normal. In n knees in which the growth plate in the upper was closed before operation the relation



ure 1. The medial side of the knee. The hatched a is the site of tenderness to palpation and the a in which a rough uneven surface can be pated.

between the length ... ligame ... accor ... to be ... knees ... were still open and for technical reasons such measurement was not possible.

OPERATIVE FINDINGS AND TREATMENT

The knee joint was explored via a medial parapatellar incision in a bloodless field with the patient under general anaesthesia. Immediately proximal to the articular surface of the medial femoral condyle the synovial membrane was found to be reddened and thickened. The site of the thickening corresponded to the area with tenderness and a palpable rough surface. On translation of the patella in a proximal direction over this area the synovial membrane folded in front of the upper cartilage-lined pole of the patella (Figure 2). On continued translation of the patella in a proximal direction the synovial cushion was forced under the patella. This occurred gradually and every time a portion of the membrane was pressed under the patella, the latter jerked. When this was repeated one experienced a sensation of crepitations in the hand manipulating the patella. The same thing happened when the patella was translated distally from its most proximal position. This finding corresponded to the retropatellar crepitations felt preoperatively.

In ... changed portion of the synovial membrane was excised together with the underlying fatty layer without interfering with the periosteum. Afterwards the crepitations could no longer be elicited.

In none of the cases was it possible to detect or feel any fissures or other changes in the cartilage of the patella or femoral condyles. The position of the patella relative to the femur was judged as normal. The amount of synovia was not increased. The menisci and the cruciate ligaments were normal in the parts that could be examined via the incision. The incision was closed in layers and the leg was immobilised in plaster from the groin to the ankle with the knee extended. The patient was allowed to walk on the leg as soon as he could. The plaster and the skin sutures were removed after 10–14 days. As a rule the patients recovered full mobility of the knee in 3–4 weeks.

Nangle and Smillie contended that the aetiology in their cases was patella alta this having caused an abnormal contact between the patella and femur In the cases presented here it was necessary to search for another explanation Primary synovitis localized to this particular area appears improbable It appears more likely that the cause was a special configuration of the patella and/or femur or some abnormal pattern of movement between them The fact that the two patients in whom the upper cartilage-lined margin of the patella was rounded off made an almost complete recovery although the thickened synovial membrane was left untouched argues for such a cause However, owing to lack of precise knowledge of the normal configuration of this special part of the patella in this age group it is not possible to say whether the form of the patella was abnormal in the patients in this material Nor could any abnormal shape of the femur or any abnormal pattern of movement between the patella and the femur be detected However, the thickening and reddening of the synovial membrane was considered definitely pathologic in all the cases, for which reason this part of the membrane as a rule was excised

In those patients in whom the symptoms recurred some time after the operation tenderness to palpation and the roughness proximal to the medial femoral ... returned This was ascribed to a ... the thickening of the synovial memb... would have been interesting to reope... these knees and then round off th... cartilage-lined corner of the pa... was not considered warranted until ... known about this condition

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REFERENCES

436–445

Lancourt J E & Cristini J A (197?) P... and patella infera *J Bone Jt S...* 1112–1115

Nangle E J (1972) Pseudochondroma... patella In *Proceedings of the Soc...* Orthopaedic Association. *J Bone J...* B 382.

Smillie I S (1974) *Diseases of the kne...* 67–72 Churchill Livingstone Edi... London

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LE FRACTURES TREATED BY FIXATION OF THE DIAL MALLEOLUS ALONE

Results in 29 Patients

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A review of 29 patients with unstable ankle fractures treated by fixation of the medial malleolus alone is presented At follow up the result in 16 patients was classified as unsatisfactory or a failure and all of these patients showed radiological signs of posttraumatic arthrosis deformans. The importance of the position of the lateral malleolus in order to prevent joint incongruity and subsequent arthrosis is emphasized

Key words ankle fractures arthrosis

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problems in orthopaedic surgery have ved more attention than the treatment of laced fractures of the ankle Opinions as he treatment of choice diverge widely, ing from closed reduction (Kristensen), 1956 Watson-Jones 1955) to rigid sive internal fixation of almost every ture as recommended by the A–O group llenegger & Weber 1963, Weber 1966) many years the position of the medial leolus was considered a cardinal point and ral authors have recommended operative ction and fixation of the medial malleolus bined with closed reduction of the lateral leolus (Muller 1945, McLaughlin & Ryder 9) In cases with a posterior tibial ment which comprised more than one rter of the joint surface it was recomnded that this be fixed separately Until ently we have followed this principle and paper presents the late results in 29 ents.

PATIENTS AND METHODS

In the 5 year period from 1969 to 1974 a total of 231 patients with displaced malleolar fractures were treated in our hospital 126 patients were treated by closed reduction and 105 by operation Forty three patients had only one fractured malleolus, while the remaining 62 patients were suffering from bi or trimalleolar fractures. Of these 62 patients, 29 had only a posterior tibial fragment fixed and the material thus comprises 33 patients treated with screw fixation of the *medial* malleolus and closed reduction of the lateral malleolus.

In four cases a posterior tibial fragment of more than one quarter of the joint surface was fixed separately At follow-up two patients had died, which left 31 patients. Two patients were unavailable so 29 patients were reviewed (94 per cent). The patients were asked to fill in a questionnaire concerning subjective symptoms, working ability and restrictions in sport. All patients were examined clinically and *X-rays* of the ankle were taken. The material consisted of 19 males and 10 females and the age distribution is shown in Figure 1 Only patients over 15 years

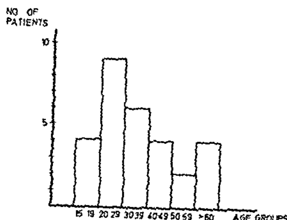


Figure 1 Age distribution of 29 patients with displaced fractures of the ankle

age were included, and the mean observation time was 4 8 years

The material was obtained retrospectively

RESULTS

The classification of the fractures was made according to Lauge Hansen (1942) and is shown in Table 1 The result was classified as follows

Excellent No pain no swelling, full or only negligible restriction of motion

... slight stiffness, no reduced capacity for work

Unsatisfactory Pain on motion, swelling, reduced capacity for work necessitating a change to light work, considerable stiffness.

Failure Unable to work, daily pain, severe stiffness

The overall results are shown in T... More than half the results were ex... satisfactory or failures.

The degree of posttraumatic arthr... determined radiographically as follows

Slight arthrosis Slight reduction of the ... space and slight formation of deposits ... joint margins.

Moderate arthrosis Joint space reduced ... 50 per cent, sclerotic configuration ... subchondral osseous tissue of the ... Moderate formation of deposits.

Severe arthrosis Joint space virtually ... existent Severe formation of deposits

The degree of arthrosis is shown in Ta... All patients demonstrated some ... arthrosis in the mild cases localized ... lateral part of the ankle joint ... relationship between the degree of art... and the result is shown in Table 4 It ... seen that even a severe degree of art... does not preclude a satisfactory result.

The result as related to the age of ... patient is demonstrated in Table 5 Seven ... of eight failures were patients under ... of age, while the excellent results ... obtained in the older age groups, ... perhaps that the handicap is greater ... younger, more active persons.

DISCUSSION

The objective of the treatment of ankle ... fractures is to achieve an anatomically ... satisfactory joint reconstruction ...

Table 1 Classification of 29 ankle fractures according to Lauge Hansen (1942)

SUPINATION–OUTWARD ROTATION STAGE IV	21
PRONATION–OUTWARD ROTATION STAGE III–IV	6
SUPINATION STAGE II	2
TOTAL	29

[T]able 2 Overall late results in 29 patients

[EX]CELLENT	:	3	13
[SA]TISFACTORY	:	10	
[UN]SATISFACTORY	:	8	16
[F]AILURE	:	8	

[Table] 3 Degree of posttraumatic arthrosis deformans in 29 patients

[SL]IGHT ARTHROSIS	:	14
[MO]DERATE ARTHROSIS	:	8
[SE]VERE ARTHROSIS	:	7
[TO]TAL	:	29

[Table] 4 The relation between late results and degree of arthrosis in 29 patients

[SLI]GHT ARTHROSIS, 14 PATIENTS		
[E]XCELLENT	:	3
[S]ATISFACTORY	:	2
[U]NSATISFACTORY	:	5
[F]AILURE	:	4
[MOD]ERATE ARTHROSIS, 8 PATIENTS		
[E]XCELLENT		0
[S]ATISFACTORY		5
[U]NSATISFACTORY		1
[F]AILURE		2
[SEVE]RE ARTHROSIS, 7 PATIENTS		
[EX]CELLENT		0
[SA]TISFACTORY		3
[U]NSATISFACTORY ·		2
[F]AILURE	:	2

Table 5 Mean age of the patients in relation to the late result

EXCELLENT	:	MEAN AGE 43
SATISFACTORY	:	MEAN AGE 32
UNSATISFACTORY	:	MEAN AGE 32
FAILURE	:	MEAN AGE 23

essential basis for optimal joint function and prevention of the development of arthrosis deformans (Cedell 1975) Many authors have shown that joint incongruity leads to arthrosis (Lewis & Graham 1940, Palmer 1941, 1944) Conservative treatment involving reduction and fixation in plaster is recommended by many surgeons (Kristensen 1949, 1956, Watson-Jones 1955, Kleiger 1961) They resort to operative treatment only in cases in which repeated attempts at reduction do not result in acceptable fracture position

Others believe that fixation of the displaced medial malleolus and of a large posterior tibial fragment with subsequent reduction of the lateral malleolus is indicated (Muller 1945, McLaughlin & Ryder 1949).

However, many authors have pointed out that non-operative reduction of the lateral malleolus seldom results in an anatomically satisfactory joint reconstruction due to interposition of ligaments, cartilage, and bone fragments (Palmer 1950, Burwell & Charnley 1965, Weber 1966, Cedell 1967)

Breitenfelder (1957) and Willenegger (1961) have shown that widening of the ankle mortise due to even minute rotation and lateral displacement of the lateral malleolus results in a diminished contact area between the tibia and the talus. Lateral subluxation of the talus means that the exact fit between the articular ridge of the tibia and the corresponding articular groove of the talus is disturbed leading to incongruity and arthrosis (Cedell 1975) In all our patients the lateral malleolar fracture healed in a position with varying degree of outward rotation, lat

proximal, and dorsal displacement, and they all showed signs of arthrosis deformans.

The question is now whether operative treatment aiming at reconstructing all components of the ankle joint is superior to more conservative measures Comparing Magnusson's conservatively treated material (1944) to his own treated by operation, Cedell (1967) found a reduction of the frequency of arthrosis deformans in supination-outward rotation injuries stage IV from 82 to 38 per cent In the present series, comparable as regards age and sex of the patients, using the same classification of the fractures, a frequency of 100 per cent was noted

The result in 16 out of 29 patients was classified as either unsatisfactory or a failure, but as the development of arthrosis deformans is a rather slow process (Hendelberg 1943), the mean observation time of 4 8 years makes a further reduction of the number of good results probable. The connection between arthrosis deformans and subjective symptoms has been discussed for many years A mild degree of arthrosis is not necessarily accompanied by subjective symptoms (Magnusson 1944, Klossner 1962) but marked arthrosis nearly always involves severe subjective symptoms (Hendelberg 1943, Willenegger 1961, Klossner 1962).

This paper supports the view that exact reposition of the lateral malleolus is essential for good joint function and the prevention of the development of posttraumatic arthrosis deformans. It also shows that this position cannot be achieved by conservative measures, and we therefore recommend operative fixation of unstable malleolar fractures.

REFERENCES

Breitenfelder H (1957) Der lange Drehbruch des ausseren Knochels (Verh Dtsch Orthop. Ges. Beiheft) *Z Orthop* **88**, 33 336

Burwell, N H & Charnley A D (1965) The treatment of displaced fractures at the ankle by rigid internal fixation and early joint movement. *J Bone Jt Surg* **47-B**, 634–660

Cedell, C.-A. (1967) Supination-outward rotation injuries of the ankle. *Acta orth* [illegible] Suppl 110

Cedell, C.-A (1975) Ankle lesions *Acta* [illegible] *scand.* 46, 425–445

Hendelberg, T (1943) Om [illegible] tibiakanten vid malleolfrakturer [illegible] kannedomen om ligament og [illegible] *Acta Soc Med upsalien* 49, 1-2

Kleiger, B (1961) The treatment of [illegible] fractures of the fibula. *J Bone Jt Surg* [illegible] 969–979

Klossner, O (1962) Late results of oper[illegible] non-operative treatment of [illegible] fractures. *Acta chir scand.*, Suppl [illegible]

Kristensen, T B (1949) Treatment of [illegible] fractures according to Lauge Hansen's [illegible] Preliminary results. *Acta chir* [illegible] 362–379

Kristensen T B (1956) Fractures of the [illegible] VI Follow-up studies. *Arch. Surg* [illegible]

Lauge Hansen, N (1942) *Ankelbrud I. Ge[illegible] diagnose og reposition* Diss. [illegible] København.

Lewis, R W & Graham W C (194[illegible]) [illegible] osteoarthritis following fracture of the [illegible] *Amer J Surg* 49, 210–218

Magnusson, R (1944) *On the late results* [illegible] operated cases of malleolar fract[illegible] Fractures by external rotation. *Acta* [illegible] *scand*, Suppl 84

McLaughlin H L & Ryder, C T (19[illegible]) [illegible] reduction and internal fixation for [illegible] the tibia and the ankle *Surg Clin* [illegible] 29, 1523–1534

Muller, G M. (1945) Fractures of the [illegible] malleolus. *Brit. med. J* 2, 320

Palmer, I (1941) Fotledens [illegible] *Nord Med.* 12, 3167–3176.

Palmer, I (1944) Arthritis deformans [illegible] behandling II Frakturer och [illegible] deformans. *Nord Med.* 21, 103–108

Palmer I (1950) Malleolfrakturer och [illegible] behandling *Nord Med.* 4, [illegible]

Watson-Jones, R. (1955) *Fractures and injuries* Vol 2, 4th ed., E. & S. Livingstone Edinburgh & London.

Weber B G (1966) Die Verletzungen des [illegible] Sprunggelenkes. In *Aktuelle Probleme* [illegible] *Chirurgie*, Vol 3 Verlag Hans Huber [illegible] und Stuttgart.

Willenegger, H (1961) Die Behandlung [illegible] Luxations-frakturen des oberen Sprung[illegible] nach biomechanischen Gesichtspunkten [illegible] *chir Acta* 28, 225–239

Willenegger, H & Weber B G [illegible] Malleolfrakturen. In *Technik der* [illegible] Sprung[illegible] *Frakturenbehandlung* Berlin/Gottingen/Heidelberg

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hop. scand 49 215–219 1978

MMETRY OF PLANTAR FLEXION STRENGTH :HE FOOT

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A study of plantar flexion strength and calf circumference in 30 conscripts is submitted It showed an asymmetry of strength amounting to 6–11 per cent (95 per cent confidence limits) The right leg was significantly stronger than the left, but there was no difference in strength between the dominant and non-dominant leg There was little correlation between circumference and strength.

Key words foot, laterality, leg circumference muscle contraction, muscular asymmetry, plantar flexion

Accepted 15 xi 77

sttraumatic reduction of strength is to be sed, the degree of difference in strength een symmetrical muscle groups must be m (Heebøll-Nielsen 1964), and it must be m also whether dominant and non-inant muscle groups differ in strength ies & Chalmers 1970) Ergometric studies normal limbs have demonstrated a ionship between maximum power and me of effective muscle tissue (Davies & eant 1975) On clinical examination and ollow-up studies, muscle strength has a been assessed by measuring circum-nce According to theoretical con-rations, however, there may be qualitative erences between normal muscles mussen & Christensen 1975) and little elation has been demonstrated between umference and isometric strength and amic endurance in previously injured bs (Damholt & Zdravkovic 1972)

TERIAL

elucidate these aspects we studied the strength plantar flexion in 30 new conscripts without previous injuries to the lower limbs and with a fairly equal distribution of side dominance The dominant leg is taken to mean the leg which the person prefers for jumping and/or for a forceful, accurate kick at a ball

Table 1 presents age, height, and weight.

Table 1 Age, height, and weight distribution of 30 conscripts

	Max	Min	Mean
Age (years)	26	19	21 1
Height (cm)	193 5	166 0	179 3
Weight (kg)	94 2	60 1	72.7

As the dominant leg 20 stated the right and 10 the left leg

METHOD

For measuring the plantar flexion strength of the foot we used an electronic strain-gauge dynamometer designed by Darcus (1953) The device for fastening the leg to it was designed by the present authors (Figure 1). When the leg is fastened in the unyielding apparatus, contraction of the calf muscles must be considered isometric In the measurements the set-up was as reported by Asmussen & Heebøll-Nielsen (1961). The scale is

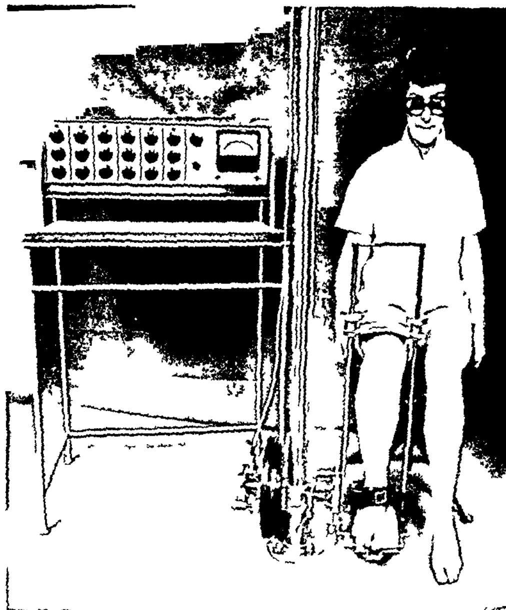


Figure 1 Darcus strain gauge dynamometer combined with the present authors device [illegible] limb

calibrated so that the strength can be read directly in kp × cm

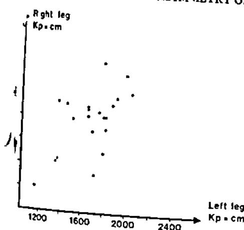
The plantar flexion strength recorded was the maximum excursion on the scale that the subject could achieve at repeated measurements. The recorded circumference refers to greatest calf circumference.

RESULTS

The ratio between strength in the right and left legs is apparent from Table 2. In 22 out of 30 persons (73.3 per cent) the r[illegible] was stronger than the left. The mean [illegible] in the right leg was 1725 kp × cm and [illegible] left leg 1630 i.e. a difference of [illegible] This difference is significant [illegible] $P < 0.01$).

Figure 2 gives the correlation be[illegible] plantar flexion strength in the r[illegible] leg The correlation coefficient is [illegible] correlation is significant ($P < 0.0$[illegible]

Similarly, Table 3 and Figure 3 [illegible]



2 Correlation between plantar flexion ngth in the right and left leg in 30 conscripts 0 68)

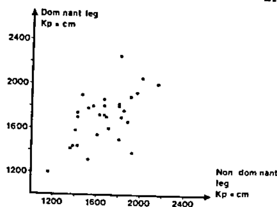


Figure 3 Correlation between plantar flexion strength of the dominant and non dominant leg in 30 conscripts (r = 0 60)

o between the dominant and non-minant leg The dominant leg had a mean ngth of 1693 kp × cm as compared with 6 kp × cm in the non-dominant leg a ference of 1 6 per cent which is not nificant ($0.4 < P < 0.5$) The correlation ween the strength in the dominant and n-dominant leg is significant (r = 0 60, 0 001)

The correlation between strength in the stronger and weaker leg is illustrated in Figure 4 The correlation is significant ($P < 0.001$) and the correlation coefficient 0 80 The mean difference in strength between the weaker and stronger leg was 149 kp × cm or 8 per cent The 95 per cent confidence limits were 97–201 kp × cm (or 6–11 per cent)

Figure 5 shows the relationship between

Table 2 Plantar flexion strength in the right and left leg of 30 conscripts

	Mean strength kp × cm	S D	Range	Per cent of persons in whom the right leg was stronger	R L in per cent of R
ight leg	1728	235	1200–2250	73 3 (22/30)	5 7
eft leg	1630	210	1160–2050		

aired t test $t = 2.989$ degrees of freedom 29 $0.005 < P < 0.01$

able 3 Plantar flexion strength in the dominant leg (D) and non dominant leg (d) in 30 conscripts

	Mean strength kp × cm	S.D	Range	Per cent persons stronger in D	D–d in per cent of D
ominant leg	1693	231	1200–2250	60 0 (18/30)	1 6
on-dominant leg	1666	225	1160–2150		

aired t test $t = 0.7291$ degrees of freedom 29 $0.4 < P < 0.5$

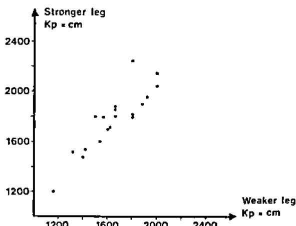


Figure 4 Correlation between plantar flexion strength in the stronger and weaker leg of 30 conscripts (r 0 80)

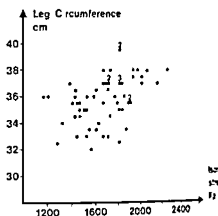


Figure 5 Correlation between calf [illegible] and plantar flexion strength in 30 [illegible] (r=0 41)

strength and circumference There is a wide dispersion of the values, indicating little relationship between the two parameters The correlation coefficient, r=0 41, is correspondingly low, but the correlation is significant (0 001 < P < 0 01)

DISCUSSION

In a study of 96 conscripts Heebøll-Nielsen [illegible]) found that a difference in strength between symmetrical muscle groups of 10 per cent was not significant, but a difference of 20 per cent was The present results of this investigation of plantar flexion strength in the feet of 30 conscripts confirm this finding, as there was a mean difference in strength between the weaker and stronger leg of 149 kp × cm or 8 per cent The 95 per cent confidence limits were 97–201 kp × cm (or 6–11 per cent) Therefore, in dealing with sequelae to traumas affecting the lower limbs it is reasonable to interpret a difference in strength in calf muscles exceeding 15 per cent as pathological

Gillies & Chalmers (1970), studying plantar flexion strength in eight normal persons, found that the dominant leg was an average of 15 8 per cent stronger than the non-dominant leg With this background they introduced a corresponding correction [illegible] strength measurement in the follow-[illegible] patients treated for rupture of the [illegible] tendon In our study the dominant leg [illegible] stronger in 60 per cent of the subjects [illegible] true, but the difference in strength was [illegible] averaging 27 kp × cm or 1 6 per cent [illegible] difference is not significant (0 4 < P < 0.5)

On the other hand, the right leg was [illegible] average, 5 7 per cent stronger than the [illegible] leg This difference is significant Even [illegible] group in which the left leg was dominant [illegible] right leg was, on average, 5 6 per [illegible] stronger than the left In a follow-up [illegible] using measurements of strength follow[illegible] trauma to the limbs, in series with a [illegible] difference in the number of right-sided [illegible] left-sided injuries, the difference in [illegible] between the right and left leg demonstrated in the present investigation might [illegible] basis for correcting the results [illegible] measurements

In two series of patients with [illegible] femoral fractures Damholt & Zdravković (1972, 1974) found low correlation [illegible] (r=0 23 and 0 27) for the relation [illegible] between circumference of the thigh [illegible] isometric quadriceps strength.

In the present study of normal persons there was a somewhat higher correlation coefficient (r=0 41) for the [illegible]

reen calf circumference and isometric tar flexion strength in the foot ertheless, the circumference is a poor ex- sion of muscle strength, as the coefficient etermination r^2 is only 0 17, meaning that iation in one parameter explains only 17 cent of the variation in the other imeter around the mean value

clusion

study of calf circumference and plantar ion strength in a series of normal persons wed

A variation of 6–11 per cent between the strength of symmetrical muscle groups (95 per cent confidence limits)

No statistically significant difference in strength between the dominant and non- dominant leg

A significantly greater strength of the right than the left leg

Little correlation between circumference and strength

REFERENCES

Asmussen, E & Heebøll Nielsen K (1961) Isometric muscle strength of adult men and women. Commun Test. Obs. Inst Dan Nat Ass inf Paral nr 11

Asmussen, E & Hohwu Christensen (1975) *Legemsøvelsernes specielle teori* 2 oplag Akademisk Forlag København

Damholt, V & Zdravkovic, D (1972) Quadriceps function following fractures of the femoral shaft *Acta orthop scand* 43 148–156

Damholt V & Zdravkovic, D (1974) Quadriceps function following fractures of the femoral shaft in children *Acta orthop scand.* 45 756–763

Darcus, H D (1953) A strain-gauge dynamometer for measuring the strength of muscle contrac tion and for re-educating muscles. *Ann Rev phys Med* 1 163–176

Davies C T M. & Sargeant A J (1975) Physiological responses to exercise in patients following fracture of the lower limb *Scand J Rehab* 7, 45–50

Gillies, H & Chalmers, J (1970) The management of fresh ruptures of the tendo Achillis. *J Bone Jt Surg* 52-A 337–343

Heebøll Nielsen K. (1964) Muscular asymmetry in normal young men. Commun Test Obs. Inst Dan Nat Ass. inf Paral nr 18

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OSTEOSARCOMA OF THE METATARSAL BONES

Review of the Literature and Report of a Case

O SNEPPEN, I DISSING, J HEERFORDT & T SCHIÖDT

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A case of osteosarcoma affecting the third metatarsal bone is [illegible] Below knee amputation was performed, but the patient developed [illegible] metastases and died 1 year after the operation. The six cases of [illegible] in the metarsal bones published so far are reviewed The prognosis [illegible] with this localization does not appear to differ from that for osteosarcoma [illegible] general

Key words osteosarcoma, metatarsal bones

Accepted 11 x.77

In his book "Fractures and Joint Injuries" Watson-Jones (1960) said, speaking of the metatarsal bones, that "sarcoma of this bone has not yet been reported in thousands of years in any country" He thereby wanted to [illegible] how absurd an erroneous diagnosis [illegible] sarcoma is when march fractures are so common at this site and to stress the serious consequences that such a mistaken diagnosis may entail and has indeed entailed (Dodd 1933)

At any rate, osteosarcomas of the metatarsal bones are extremely rare Reviewing the literature we found only six cases. However, this probably does not give a true impression of the incidence, as in many reports on osteosarcoma the exact site of the tumour is not stated Table 1 lists the materials published so far in which the site has been sufficiently clearly elucidated It will be seen that metatarsal osteosarcomas make up about 0 5 per cent of the total number of osteosarcomas on record On the basis of the incidence of osteosarcomas in general (Coley 1949), this corresponds to an incidence of metartarsal osteosarcomas of one case in 20 million people

Table 1 Occurrence of osteosarcomas aff[illegible] metatarsal bones in the materials published [illegible] Only materials giving sufficient information [illegible] the exact location of the tumours are inclu[illegible] the Table

	Number of osteo-sarcomas	Met[illegible]
Code (1955)	133	[illegible]
Coventry & Dahlin (1957)	430	[illegible]
Lindbom et al. (1961)	96	[illegible]
Lee & MacKenzie (1964)	160	[illegible]
McKenna (1966)	258	[illegible]
Marcove et al. (1970)	145	[illegible]
Jenkin et al. (1972)	62	[illegible]
Scranton et al. (1975)	54	[illegible]
Price et al. (1975)	125	[illegible]
Present material*	49	[illegible]
Total	1522	[illegible]

* Dissing et al. (In press)

Among a 10-year material from 1[illegible] 1973 we found out of 49 cases of osteosar[illegible] one which was localized to a metatarsal [illegible]

E REPORT

ırly March 1971 a 22-year-old imbecile man U case rec. 20654) noticed a swelling on the ım of his left foot. It caused mild pain and lty in wearing shoes. When he was first seen nths later there was a mass, "half the size of a ı egg", on the middle of the dorsum of the left Radiography on May 10th showed a tumour e third metatarsal bone (Figure 1) In spite of adiological finding the tumour was diagnosed arily as a benign osteochondroma, and in the s hospital an *en bloc* non-radical excision of the ur and the affected metatarsal bone was ormed on June 24th. At the operation the ur was found to be infiltrative, involving the unding soft tissues, especially in the sole. The surface of the removed tumour was yellowish white and lobulated Histological examination, as well as subsequent revision of the preparations, revealed a chondroblastic osteosarcoma (Figure 2). The patient was then referred to the Department of Orthopaedic Surgery, Rigshospitalet, University of Copenhagen, where he was admitted in July At that time there were no signs of dissemination of the tumour, in particular the chest radiography was normal. On July 20th a below-knee amputation was carried out. The amputation specimen contained in the forefoot ...

same year



1 Radiography showing a chiefly osteolytic involving the proximal two-thirds of the metatarsal bone In the large calcified soft component of the tumour a spicular pattern seen in places

DISCUSSION

It is a fairly common assumption that osteosarcomas affecting the hand and foot have a relatively favourable prognosis (Coventry & Dahlin 1957) Since, however, these sites are extremely rare, the prognostic evaluation must be based upon the fact that in some materials the prognosis is better for tumours localized distally than proximally in the limbs. This is in accordance with the experience of Marcove et al. (1970) in whose material pulmonary metastases occurred fairly late when the tumours were localized distally to the knee and elbow Moreover, Dahlin & Coventry (1967) and Jaffe (1958) found a better 5-year survival after tumours affecting the tibia than the femur Jeffree et al (1975) found relatively few extrapulmonary metastases from tumours in the tibia Others (Stanley & MacKenzie 1964, Scranton et al. 1975) could not confirm this finding In any case, the differences found are rather slight, and it was only in Dahlin & Coventry's material that the difference was statistically significant ($P < 0.01$).

However, if there is a relationship, viz , that a more peripheral site affords a better prognosis, metatarsal osteosarcomas would be expected to have a particularly long survival. Reports published so far have not provided any evidence of this kind. Coventry & Dahlin (1957) reported two patients with metatarsal osteosarc...

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try, M. B & Dahlin, D C (1957) Osteogenic coma A critical analysis of 430 cases. *J ne Jt Surg* 39-A, 741–756
, D C. & Coventry, M B (1967) Osteogenic coma A study of six hundred cases. *J Bone Surg* 49-A, 101–110
g, I, Heerfordt, J, Schiodt, T & Sneppen, (1978) Osteosarcomet En prognostisk dering på basis af 49 tilfaelde *Ugeskr Laeg* press)
H (1931) [illegible] *J*
[illegible] *ous*
[illegible] &
iger, Philadelphia.
G M, Price, C H G & Sissons, H A. 75) The metastatic patterns of osteosarcoma
[illegible]
m, Å, Soderberg, G & Spjut, H J (1961) osarcoma A review of 96 cases. *Acta ol. (Stockh.)* 56, 1–19
Marcove, R. C, Miké, V, Hajek, J V, Levin, A. G & Hutter, R V P (1970) Osteogenic sarcoma under the age of twenty-one A review of one [illegible]
osteogenic series. An analysis of 552 cases. *J Bone Jt Surg* 48-A, 1–26
Price, C H G, Zhuber, K., Salzer-Kuntschik, M, Salzer, M, Willert, H G, Immenkamp, M., Groh, P, Matejovsky, Z & Keyl, W (1975) Osteosarcoma in children. A study of 125 cases. *J Bone Jt Surg* 57-B, 341–345
Scranton, P E, DeCicco, F A., Totten, R. S & Yunis, E J (1975) Prognostic factors in osteosarcoma *Cancer (Philad.)* 36, 2179–2191
Stanley Lee, E & Mackenzie, D H (1964) Osteosarcoma A study of the value of preoperative megavoltage radiotherapy *Brit J Surg* 51, 252–274
Watson-Jones, R (1960) *Fractures and joint injuries*, 4th ed., Vol. I, p 347 Livingstone, Edinburgh and London.

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PRACONDYLAR FRACTURE OF THE HUMERUS CHILDREN

ong Term Follow-up Study of 107 Cases

O VAHVANEN & KARI AALTO

ra Children's Hospital, Helsinki Finland

A total of 107 cases of supracondylar fracture of the humerus in children were examined after a follow-up period of 8 to 18 years. No serious complications were found Conservative treatment gave good results and open reduction was seldom indicated Rotational displacement and displacement in the frontal or sagittal plane remodelled by the end of the growth period, whereas tilting of the distal fragment into varus or valgus remained The position of reduction should be checked roentgenologically until bony consolidation occurs by measuring Baumann's angle or the carrying angle and rereductions should be performed within 2 weeks

Key words supracondylar fracture, humerus children, Dunlop's traction long term follow up

Accepted 12 x 77

pracondylar fracture of the humerus is a nmon fracture in children Between 40 and per cent of all fractures in the elbow gion are of this type (Blount et al 1951, ount 1955, El-Sharkawi & Fattah 1965, arikson 1966) The treatment of these ctures presents certain difficulties even to perienced surgeons. It is common to assify supracondylar fractures into two ain groups according to the direction of the rce of the injury the rare flexion type hich constitutes 1 per cent of cases cording to Blount (1955) and the more mmon extension type of fracture Good sults after closed reduction and immobilization of the elbow joint into flexion and ronation have been reported by many uthors (Baumann 1929, Siris 1939, Blount et l. 1951, Blount 1955, Watson-Jones 1962, harnley 1963, Sharrard 1971, Izadpanah 973) Many extension-type fractures may be mmobilized in extreme flexion with a collar and cuff, without the use of plaster (Blount et al 1951 Watson-Jones 1962, Charnley 1963)

El-Sharkawi & Fattah (1965) treated supracondylar fractures with reduction and immobilization of the elbow joint in full extension and supination Baumann (1929) recommended traction in severely displaced cases, especially if the patients came for treatment late Skin traction after reduction was introduced by Dunlop (1939) The same method was used later by Allen & Gramse (1945) Mitchell & Adams (1961) and Dodge (1972) Hagen (1964) used skin traction over the head. Skeletal olecranon traction was used by Høyer (1952), Madsen (1955), Smith (1960, 1967) and Rosman (1975). This method was preferred as treatment ... severely displaced fractures by ... (1971) and Tachdjian (1972) Swenson ... Flynn et al (1974) and Fowles ... (1974) preferred closed reduction ... fracture with fixation of the ...

percutaneous Kirschner or Steinmann wires

This paper presents an investigation of the treatment of supracondylar fractures of the humerus in children comparing treatment by closed reduction and plaster immobilization with treatment by reduction, traction and plaster immobilization, as regards end results and growth disorders. We also tried to determine the range of displacement which could be accepted primarily if a good end result was to be obtained

PATIENTS AND METHODS

The series consisted of 107 dislocated supracondylar fractures of the humerus in children under 15 years of age, treated as inpatients at Aurora Children's Hospital Helsinki Finland in the period in 1957–1967 Of the total number of 176 patients, 36 were excluded from our study because there was neither fracture dislocation nor reduction. 107 out of 140 inpatients (76 per cent) were contacted and examined by the authors during 1973–1975 Some of the remaining 33 patients (33/140) were excluded because of the unacceptable quality of the primary radiographs.

The age and sex distribution is shown in Figure 1 The age of the patients varied from 1 5 to 14 years with an average of 7 years. The highest frequency of fractures was found in the age group 3 to 9 years The ratio between left and right ...s was 67 40 Fractures were sustained most ... during the summer and autumn. The cause of the injury is presented in Table 1 There ... no open fractures. The fractures were classified into five groups according to the mechanism of the trauma and the degree of dislocation (Figure 2) Flexion type fracture (groups II and III) occurred in 12 cases (11 per cent), and the extension type (groups IV and V) in 87 cases (81 per cent) Eight cases (8 per cent) with only rotational displacement made up group I

Treatment was closed reduction and plaster immobilization in 35 cases (32 per cent) reduction and Dunlop's skin traction in 58 cases (54 per cent) (Figure 3) Seven cases (7 per cent) were immobilized without reduction and seven cases (7 per cent) were treated surgically (Table 2). In the seven surgically treated cases conservative reduction was tried first without success, but because of loss of the pulse in the radial artery in four cases and failure to maintain an acceptable position of the fracture with closed reduction in three cases, open reduction was performed

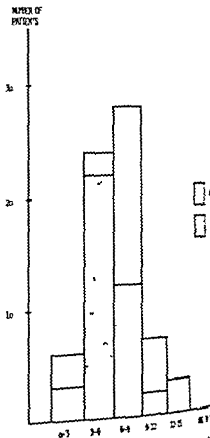


Figure 1 Distribution of the ... according to age in years at the time of ...

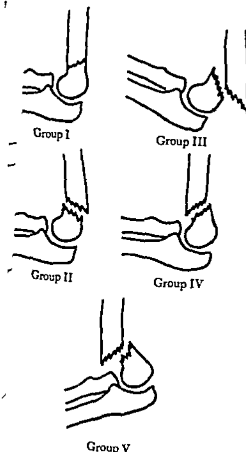
including fixation of the fragments ... wire or cerclage

The flexion type fractures were ... with the elbow joint in full extension ... tion Dunlop's skin traction was ... severe posterior dislocation and ... reduction could not be ... Rereductions were done in 25 cases ... maintained for 4 to 28 days, ... traction was removed and the arm was ... ed with plaster The total period of ... tion lasted on average 30 days.

Residual deformity was studied ... In order to estimate varus or valgus ... angle between the lateral epiphyseal ...

Table 1 Mechanism of the ...

Fall from a height
Fall on the same level
Sports accident
Compression/twisting
Total



ure 2 *The distribution of the fractures in the ferent groups of displacement in the sagittal ne (Henrikson 1966, with the author's mission)*

oup I

displacement (according to Henrikson) but the it cases in our series with only slight rotational placement are included in this group

oup II

x of angle (<20°) dorsally and/or with rior displacement less than the breadth of the e Four patients.

up III

x of angle (>20°) dorsally and/or anterior dis-ement equal to the breadth of the bone Eight ents.

up IV

x of angle (<20°) anteriorly and/or dorsal dis-ement less than the breadth of the bone nty two patients.

up V

t of angle (>20°) anteriorly and/or dorsal d s-ment of the distal fragment by more than the dth of the bone Sixty-five patients.

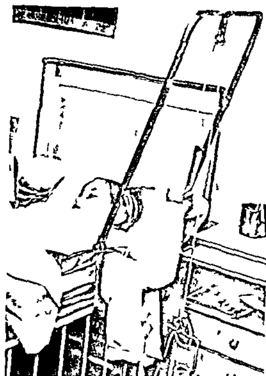


Figure 3 Modified Dunlop s skin traction with posterior plaster splint

longitudinal axis of the humerus was measured according to Baumann (1929) (Figure 4) After the closure of the epiphyseal lines, an analogous com parison of the angle between the trochlear axis and the longitudinal axis of the humerus, the carrying angle (CA) was made The cubital axis was also measured clinically and the range of motion and the patients subjective complaints were registered.

The duration of the follow-up ranged between 8 and 18 years, on average 12 years. The age of the patients at the follow up was 12 to 26 years, average 18 years.

RESULTS

Primary results

The primary roentgenological results evaluated according to the criteria in Table 3 were good in 59 cases (55 per cent), fair in 44 cases (41 per cent) and poor in 4 cases (4 per cent) (Table 4) All of the seven fractures treated surgically healed without any com-

percutaneous Kirschner or Steinmann wires

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PATIENTS AND METHODS

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The age and sex distribution is shown in Figure 1 The age of the patients varied from 1 5 to 14 years with an average of 7 years. The highest frequency of fractures was found in the age group [illegible] to 9 years. The ratio between left and right [illegible] was 67 40 Fractures were sustained most [illegible]dy during the summer and autumn. The [illegible]use of the injury is presented in Table 1 There [illegible] no open fractures. The fractures were classified into five groups according to the mechanism of the trauma and the degree of dislocation (Figure 2) Flexion type fracture (groups II and III) occurred in 12 cases (11 per cent) and the extension type (groups IV and V) in 87 cases (81 per cent) Eight cases (8 per cent) with only rotational displacement made up group I

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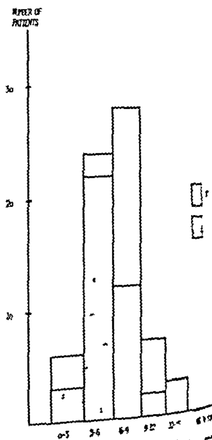


Figure 1 Distribution of the [illegible] according to age in years at the time of [illegible]

including fixation of the fragments with [illegible] wire or cerclage.

The flexion type fractures were [illegible] with the elbow joint in full extension [illegible] tion Dunlop's skin traction was used [illegible] severe posterior dislocation and [illegible] reduction could not be [illegible] Rereductions were done in 25 cases. [illegible] maintained for 4 to 25 days, after [illegible] traction was removed and the arm was [illegible] ed with plaster The total period of [illegible] tion lasted on average 30 days.

Residual deformity was studied [illegible] In order to estimate varus or valgus [illegible] angle between the lateral epiphyseal [illegible]

Table 1 Mechanism of the [illegible]

Fall from a height	[illegible]
Fall on the same level	[illegible]
Sports accident	[illegible]
Compression/twisting	[illegible]
Total	[illegible]

otomy was performed because of return
d peripheral pulse The recovery was
ntful and complete

esults

roentgenological results at the follow up
, evaluated according to the criteria
in Table 3, were good in 87 cases (81
ent), fair in 12 cases (11 per cent) and
in 8 cases (8 per cent) (Table 5).
e primary and late results in the groups
d with plaster immobilization and those
d with traction and plaster immobiliza
are seen in *Table 6* The late results do
liffer significantly from the primary ones
$2.33 < \chi^2_{5\%} = 5.99$)
nically the varus/valgus deformity, i e
difference in the cubital angle on both sides,
lated with that of the roentgenological
ing angle Restriction of extension by
)° was present in two cases limitation of
on by less than 10° in ten cases and
een 10 and 20° in another four cases
itional movement was normal in all cases.

In the late follow up study seven cases were classified as poor because of varus, and one case because of valgus angulation The valgus angulation and two cases of varus amounted to 15° None of these patients required any treatment In five cases with 25° of varus however a corrective osteotomy was performed

Comparison of primary and late results

In comparing the results of the primary and late follow up examinations, it is quite clear that rotation and displacement of the distal fragment in the frontal or sagittal plane, resulting in a primary classification of fair or poor, had disappeared at the time of follow-up The only exceptions were three cases with tilting of the distal fragment in two cases varus of 15°, and one case valgus of 15° In the evaluation of the eight cases classified as poor at the follow up compared with the four cases with this classification after the primary fracture treatment we could see the following points of interest Of these

Table 5 Late roentgenological results

oup	I	II	III	IV	V	Total	Per cent
d							
r	7	4	5	17	54	87	81 3
r	—	—	1	2	9	12	11 2
	1	—	2	3	2	8	7 5
tal	8	4	8	22	65	107	100 0

le 6 Comparison of the primary and late results in cases treated by closed reduction and plaster and reduction combined with skin traction

thod	Primary result			Late result		
	Good	Fair	Poor	Good	Fair	Poor
luction and ster cases)	20	12	3	27	3	5
uction and tract on cases)	30	27	1	50	5	3
al (93 cases)	50	39	4	77	8	8

plications. Volkmann's contracture did not develop in any of the cases. A transient radial nerve injury was present in two patients (2 per cent) In four cases (4 per cent) roentgenological changes of myositis ossificans were seen, which later disappeared completely.

In our series there were vascular complications in four cases (4 per cent) Loss of pulse in the radial artery was found after the fracture reduction and surgery was performed immediately. In each of these four cases the brachial artery was found to be compressed between the fracture fragments. No

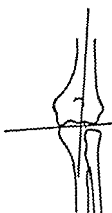

Figure 4A Carrying angle


Figure 4B Baumann's

Table 2. Methods of treatment

Group	I	II	III	IV	V
Immobilization with plaster splint	5	—	—	2	—
Closed reduction and plaster splint	3	4	4	11	13
Closed reduction and Dunlop traction	—	—	3	9	46
Open reduction osteosynthesis/traction	—	—	1	—	6
Total	8	4	8	22	65

Table 3 Criteria used in the evaluation of roentgenological results Dislocation of the distal fragment

Result	Ad latum*) AP projection	Ad latum*) Lateral projection	Ad axim	Tilting	[illegible]
Good	≤1/4	≤1/4	≤15°	≤ 5°	[illegible]
Fair	≤1/2	≤1/2	≤20°	≤10°	[illegible]
Poor	>1/2	>1/2	>20°	>10°	[illegible]

*) Displacement measured as part of the diameter of the bone

Table 4 Primary roentgenological results

Group	I	II	III	IV	V	Total
Good	7	4	3	15	30	59
Fair	1	—	5	6	32	44
Poor	—	—	—	1	3	4
Total	8	4	8	22	65	107



5 (a) Transverse fracture of the left humerus (January 6) in a 77 year-old woman (b c) X rays -patient at follow-up on October 15 Position of fracture had not changed since January 21 when bility of arm had been so good that the patient was satisfied and declined further treatment

verse fracture of the right humerus and treated with a hand sling but within 2 , against medical advice the patient ned to work where his activities ded, among other things, lifting pans e head height Healing was delayed with k of pseudarthrosis so that 2 months the accident the arm was placed in a ico-brachial plaster to prevent further ssive use of the arm The plaster was, ever split to permit free movement of the ulder and elbow 2 months later the ure was united.

rtening of the arm In transverse fractures complication was rare if the patient was bulant. A shortening of a few centimetres urred in two elderly patients who because other injuries were bed ridden however, fracture fragments remoulded and the result was functionally satisfactory

Some shortening also occurred in association with the healing of oblique or spiral fractures, but again such shortening caused no functional impairment

Angulation This complication did not occur to any significant extent in patients with oblique or spiral fractures. Transverse fractures occasionally showed an open angle of 10–15°, usually anteriorly but there was no limitation of function

Impairment of function of the upper limb joints A temporary impairment of shoulder movement was noted in elderly patients in whom a fracture line extended towards the neck of the humerus. None of the patients had any impairment of movement in the elbow, wrist or hand

Re fracture One case occurred The patient was an 84-year-old man with advanced arthrosis deformans coxae who had an

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PROLIFERATION OF BONE MARROW AND THYMUS CELLS AND INCREASED OSTEOCLASIA AFTER ANTIGENIC CHALLENGE IN RATS

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Department of Orthopaedic Surgery, Malmö General Hospital
University of Lund, Malmo, Sweden.

Injection of a single dose of an antigenic substance (sheep [illegible] puscles) in young rats results in a significant rise in the [illegible] in bone marrow (and in thymus) and in addition a significant [illegible] number of osteoclasts in the metaphyses of the ribs. This [illegible] teoclasia appears 1 day after the peak values of the bone [illegible] thymus mitoses. This and earlier investigations make it probable [illegible] is a causal relationship between bone marrow stimulation and [illegible] teoclasia

Key words bone marrow, thymus, osteoclasts antigen [illegible]

Accepted 1.xi 77

Standardized bleeding, injection of calcium and EDTA, stimulate the rate of mitosis in bone marrow and thymus in rats (Perris & Whitfield 1967a b, Perris et al 1971) The common factor in this mechanism is a parathyroid–dependent hypercalcemia The authors of the present paper have shown that fractures of the femur (Hulth & Johnell 1976a), partial aspiration of bone marrow (Hulth & Johnell 1976b) and soft tissue wounds (Johnell 1977), in rats, also result in stimulation of mitosis of intact bone marrow and of thymus. Whether or not this reaction is also governed by PTH is not clear, but hypercalcemia occurs at fractures. In addition, fracture of the femur and bleeding in rats result in proliferation of bone resorbing osteoclasts in rib metaphyses (Johnell & Hulth 1977) Perris & Morgan (1976) have related in a review article an unpublished investigation showing that injection of an antigen, red blood corpuscles of sheep (S–RBC), in rats, also causes an increased mitosis rate 3 days after the injection The question is does increased mitosis rate in bone marrow *per se* result in [illegible] teoclasia. We have therefore [illegible] of antigen injection on the [illegible] bone marrow and on the [illegible] teoclasts.

MATERIAL AND METHODS

Three groups of 40 42, and 30 rats [illegible] weighing 120–130 g were used [illegible] including a control group of 7 [illegible] groups were used for osteoclast [illegible] for mitosis counting All the [illegible] were given intravenously in a tail [illegible] S–RBC, the first group, a [illegible] S–RBC in saline = $2.1 \times 10^{[illegible]}$ RBC [illegible] two groups 20 per cent S–RBC [illegible] RBC/liter The animals were sacrificed [illegible] of 6–7 rats after 1, 2, 3 and 5 days and [illegible] first groups also after 7 days. The [illegible] be in good condition and were [illegible] influenced by the antigen.

Osteoclast study

Blood was collected to determine Ca [illegible] and hematocrit. In all rats the [illegible] fifth ribs were taken out. The [illegible]

d for approximately 20 hours in a 10 per olution of EDTA, containing 0 1 M tris The bone was then washed in cold saline, frozen in liquid nitrogen and then cut in a ite, 5–6 sections 10μ thick being made ctions were cut at 30μ intervals in order to ize the appearance of the same osteoclast in nt sections. The sections were stained for ic dehydrogenase activity by the method of with nitroblue tetrazolium salt as the H- or (Tatevossian 1973).

osteoclast count was carried out a) in the ular bone of the metaphysis of the rib and ng a predeterm

asts occurring in the marrow cavity were also ed.

um albumin was determined by the cresol green method, serum calcium being analyzed by flame photometry Hematocrit aken in all animals.

ns study

rats were given two injections of colchicine peritoneally, the first 6 hours (0 2 mg/100 g ial) and the second 3 hours (0 2 mg/100 g ial) before the rats were sacrificed by ether choice of two injections of colchicine was e to prevent the escape of cells in metaphase the initial block All animals were given the ctions at the same time the first injection ween 8–8 30 a m., in order to avoid the adian fluctuations in mitotic activity of bone row and thymus cells (Hunt & Perris 1974)

The thymus gland and femoral bones were oved. Thymocyte and bone marrow cell pensions were prepared in a balanced glucose s medium [5 5 mM glucose, 5 0 mM KCl 3 mM $CaCl_2$ 1 0 mM $MgSO_4$ 5 0 mM Na_2 O_4, 120mM NaCl, 5 0 mM Tris buffer 7.2)]. The thymocyte suspension was pared by mincing the gland in the medium th scissors, the resulting suspension being ered through gauze. To prepare the suspension bone marrow cells, the ends of each femur were oved and the core of marrow was "washed t" with 1 5 ml of the medium and then persed by passing the tissue several times rough a syringe with an 18 gauge needle. Then th thymus and bone marrow suspensions were ntly centrifuged.

Samples of the cell suspensions were placed on ides and immediately fixed in alcohol and stained th hematoxylin and eosin. The slides were ored for the percentage of the total cell population in metaphase Each preparation had two slides and on each at least 500 cells were counted (a total of at least 1000 cells were counted) During the counting procedure the slides were labeled in code

RESULTS

Injection of 20 per cent S-RBC resulted in a significant increase ($P<0\ 001$) in the number of osteoclasts on the 3rd day with the level remaining high–until the 5th day after injection (Figure 1) Ca was normal for the first few days but showed a slight, though not definitely significant, increase on the 5th day Other changes noted were significant increases in albumin[4] on the 2nd day and in hematocrit on the 3rd day after injection After injection of the smaller dose, 10 per cent S–RBC, there was also a significant increase ($0\ 01>P>0\ 001$) in osteoclasts on the 3rd day after injection In these animals there was no increase in Ca[5], which was also true for the hematocrit.

The results of the mitosis counting of bone marrow cells and thymus cells are shown in

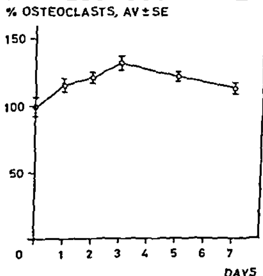


Figure 1 Percentage changes in osteoclast number in rib metaphysis after injection of a single dose of 20 per cent S–RBC The osteoclast number in the control animals is expressed as 100 per cent

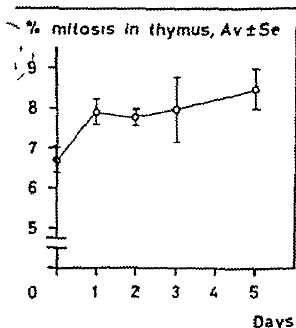
Figure 2a and b In control animals 6 hours *after the first colchicine injection* 16 8 per cent of the bone marrow population was arrested in metaphase Similar figures for the thymocytes arrested in metaphase were 6 7 per cent The increase in bone marrow cells in metaphase was significant after 1 day and highly significant after 2 days Thereafter there was a return towards normal on the 5th day

The increase in mitosis among thymocytes was highly significant on the 1st and 2nd day after injection of antigen The course after the 2nd day is impossible to determine because the values were too widely spread

DISCUSSION

In the experiments performed we have shown that injection of an antigenic substance (S–RBC) results in a significant increase in the number of mitoses in bone marrow (and also *in thymus*) *In addition the antigen* resulted in a significant rise in the number of osteoclasts in rib metaphyses in rat We were not able to perform the osteoclast counting and mitosis counting in the same ... because colchicine is known to dep... amount of osteoclasts in bone marrow ... et al 1973) Our experiments ... that the maximal effect on mitosis ... bone marrow cells occurs on the 2nd ... *whereas the maximal osteoclast effect* ... the 3rd day In experiments with ... in rats performed earlier the maximal ... mitosis and osteoclasts reached their ... values after 1 day (Hulth & Johnell ... Johnell & Hulth 1977)

An immune response and trauma ... effect in common viz. an increase ... *mitosis* of bone marrow cells The ... marrow stimulation after bleeding ... to a parathyroid-dependent hyper... Hypercalcemia also occurs after bone ... In the present experiments there was ... *insignificant increase in serum cal*... antigenic challenge The insignificant ... in serum calcium after antigen ... another mechanism for osteoclast ... substances producing osteoclast ... of bone have been investigated during ... few years. In addition to PTH



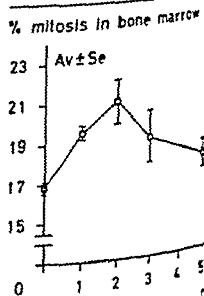


*Figure 2a and b Increase in the number of mitoses in thymus (*a) and in bone marrow ... injection of a single dose of 20 per cent S RBC*

...tamin metabolites, osteoclast activating ...r (OAF) produced *in vitro* by mitogenic ...ulation of lymphocytes (Horton et al ...), and prostaglandins (Deitrich & Raisz ...) have also been the subject of study In ...ection with immune response, pro...andins appear to mediate a complement ...ndent effect of serum on osteoclastic ... resorption (Dietrich & Raisz 1975) It is ...ible therefore that the increased os...lasia in this experiment depends on pro...landins.

...respective of the substance which ...lates the increased osteoclastic activity ...e appears to be a mutually dependent ...tionship between increased mitotic ...vity of bone marrow cells and increased ...eoclastic activity This provides an in...esting insight into the function of bone as ...organ in which its two parts are intimately ...endent on each other This aspect, though ...t new, is often overlooked It is impossible ...wever, at this stage of the research, to ...ly the experimental findings to human ...eases, especially to different types of os...oporoses.

...FERENCES

...etrich, J W & Raisz, L G (1975) Prostaglandin in calcium and bone metabolism Clin. Orthop 111, 228–237

...orton, J E. Raisz L G Simmons, H A Oppenheim J J & Mergenhagen, S. E (1972) Bone resorbing activity in supernatant fluid from cultured human peripheral blood leukocytes. *Science* 177, 793–795

Hulth, A. & Johnell, O (1976a) Cell proliferation in the bone marrow and thymus following fractures in rats. *Clin. Orthop* 120, 260–263

Hulth, A. & Johnell O (1976b) Cell proliferation in the bone marrow and thymus following partial bone marrow aspiration. *Experientia (Basel)* 32, 1577–1578

Hunt, N H & Perris, A D (1974) Calcium and the control of circadian mitotic activity in rat bone marrow and thymus *J Endocrinol* 62, 451–462.

Johnell, O (1977) Cell proliferation in the bone marrow and thymus following soft tissue damage *Acta orthop scand* 48, 433–435

Johnell, O & Hulth, A (1977) Proliferation of osteoclasts in rat bone following bleeding and femoral fractures. *Calcif Tiss Res* 23, 241–244

Perris, A. D & Whitfield J F (1967a) Calcium and the control of mitosis in the mammal *Nature (Lond)* 216, 1350–1351

Per...

550–563

Perris, A D, MacManus, J P, Whitfield, J F & Weiss, L A. (1971) Parathyroid glands and mitotic stimulation in rat bone marrow after hemorrhage *Amer J Physiol* 220, 773–778

Perris, A D & Morgan, J I (1976) The interaction of divalent cations, hormones and cyclic nucleotides in the control of mitosis *Calcif Tiss Res (Suppl)* 21, 15–20

Raisz, L. G Holtrop M E. & Simmons H A (1973) Inhibition of bone resorption by colchicine in organ culture. *Endocrinology* 92, 556–562.

Tatevossian, A. (1973) Effect of parathyroid extract on blood calcium and osteoclast count in mice *Calcif Tiss Res* 11, 251–257

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BONE GROWTH ALTERATIONS RESULTING FROM APPLICATION OF CO_2 LASER BEAM TO THE EPIPHYSEAL GROWTH PLATES

An Experimental Study in Rabbits

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The CO_2 laser beam was used to create defects 3 mm in depth in the [illegible] growth plate of one femur in a group of 59 rabbits. In most of the [illegible] rabbits in which the defect was created on the lateral aspect of the [illegible] epiphyseal plate the procedure resulted in the subsequent development [illegible] valgus deformity and shortening of the femur. In most of the [illegible] rabbits [illegible] which defects were produced both medially and laterally to the epiphyseal [illegible] plate there was a subsequent marked shortening of the bones. Histo[illegible] studies revealed that the laser-induced defects of the growth cartilage [illegible] epiphysiodesis and premature disappearance of the epiphyseal [illegible] plates.

Key words: carbon dioxide laser, epiphysiodesis, epiphyseal [illegible] cartilage

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[illegible]tudies performed by Verschueren et al [illegible] 75) showed that the use of the carbon [illegible]oxide laser beam for osteotomy results in [illegible]ealing without delayed union or pseudoarthrosis, and work done in our Experimental Surgery Unit has shown that bone defects produced by laser beams subsequently fill with new bone. These observations led to the hypothesis that application of the laser beam to the epiphyseal growth plate would produce a defect which would become replaced by bone and would thereby induce an alteration in bone growth. The present study was undertaken to determine the validity of this hypothesis.

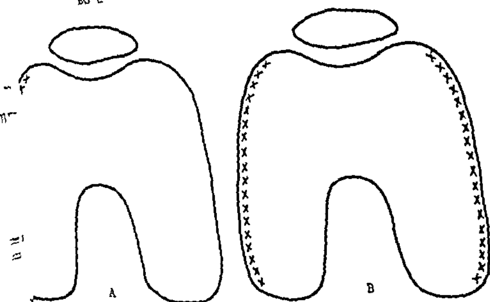
MATERIAL AND METHODS

The experimental material of this [illegible] comprised a total of 59 rabbits from 3–4 w[illegible]ks of age and weighing 800–900 g. In each animal the [illegible] distal femoral epiphysis was treated with the [illegible] beam, the left side thus serving as a control [illegible] animals were divided into two groups [illegible] group (32 animals) an almost [illegible] 3 mm in depth was produced on the lateral [illegible] the epiphyseal growth plate exposed through [illegible] small incision in the skin (Figure 1A). In the [illegible] group (27 animals) similar defects were [illegible] both on the medial and lateral aspects [illegible] epiphyseal growth plate (Figure 1B). The [illegible] were sacrificed from 10 days to 15 weeks [illegible] induction of the defect. Both femora were [illegible] dissected out, X-rayed and measured [illegible] the distal portions of both femora were [illegible] and examined microscopically.

Anesthesia during the operation [illegible] consisted of intravenous [illegible] Nembutal (pentobarbitone), 30 mg per [illegible] weight.

The "Sharplan 791"* CO_2 laser [illegible] used with an output of 7–10 watts.

* Produced by "Laser Industries Ltd" [illegible]



1A 1B Schematically-drawn horizontal sections of the distal femoral epiphysis at the level of the plates The crosses indicate the extent of the defects in each group of animals

ULTS

roscopic findings

rations in the growth of the femurs were d in 54 of the 59 rabbits. Among the 32 which the defect was produced on the al aspect of the epiphyseal growth plate showed the development of a valgus rmity which became evident at the end of third week and was maximal 12 weeks r the procedure

Then compared with the control femurs, operated femurs were shorter (Figure 2) 16 weeks there being an average shorten of 5 2 mm. In three animals in this group re was no difference between the treated l control sides. Among the 27 rabbits in ich the defect had been induced both dially and laterally the most prominent ding was the marked shortening of the erated femurs in 25 animals, which reached average of 8 8 mm 16 weeks after the procedure. The metaphyseal reg on of the erated femurs appeared to be expanded th callus formation on the medial and teral aspects (Figure 3) In four animals ere was a valgus deformity of the distal femoral epiphysis in addition to the shortening In two animals in this group there was no difference between the treated and control sides.

Microscopic findings

In both groups of rabbits the defect of the epiphyseal growth plates was found to have been replaced by bone which formed a bridge between the epiphyseal and metaphyseal parts of the femur and which resembled the callus formation seen at fracture sites (Figure 4) Evidence for the formation of these bone bridges was already found in the animals sacrificed as early as 10 days and by 3 weeks they were seen to be fully formed From 5 to 7 weeks after the procedure the epiphyseal plates were found to be narrowed and the number of cells in the cartilage columns decreased in comparison with the control side In animals sacrificed 9 weeks or more after the operation there was no epiphyseal cartilage on the operated side (Figure 5A) whereas on the control side it was still present, corresponding with the animal s age (Figure 5B) In some specimens there was a thin cortical plate of bone

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BONE GROWTH ALTERATIONS RESULTING FROM APPLICATION OF CO_2 LASER BEAM TO THE EPIPHYSEAL GROWTH PLATES

An Experimental Study in Rabbits

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The CO_2 laser beam was used to create defects 3 mm in depth in the distal growth plate of one femur in a group of 59 rabbits. In most of the 32 rabbits in which the defect was created on the lateral aspect of the epiphyseal plate the procedure resulted in the subsequent development of valgus deformity and shortening of the femur In most of the 27 rabbits in which defects were produced both medially and laterally to the epiphyseal plate there was a subsequent marked shortening of the bones. Histological studies revealed that the laser induced defects of the growth cartilage led to epiphysiodesis and premature disappearance of the epiphyseal growth plates.

Key words carbon dioxide laser, epiphysiodesis epiphyses growth cartilage

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Studies performed by Verschueren et al (1975) showed that the use of the carbon dioxide laser beam for osteotomy results in healing without delayed union or pseudoarthrosis, and work done in our Experimental Surgery Unit has shown that bone defects produced by laser beams subsequently fill with new bone These observations led to the hypothesis that application of the laser beam to the epiphyseal growth plate would produce a defect which would become replaced by bone and would thereby induce an alteration in bone growth The present study was undertaken to determine the validity of this hypothesis.

MATERIAL AND METHODS

The experimental material of this study comprised a total of 59 rabbits from 3–4 weeks of age and weighing 800–900 g In each animal the right distal femoral epiphysis was treated with the laser beam, the left side thus serving as a control. The animals were divided into two groups. In one [illegible] both on the medial [illegible] epiphyseal growth plate (Figure 1B). The animals were sacrificed from 10 days to 16 weeks after induction of the defect. Both femurs were then dissected out X rayed and measured. Sections of the distal portions of both femurs were prepared and examined microscopically

Anesthesia during the operation preceding consisted of intravenous administration of Nembutal (pentobarbitone), 30 mg per kg of body weight

The "Sharplan 791" CO_2 laser apparatus* was used with an output of 7–10 watts.

* Produced by "Laser Industries Ltd." Israel

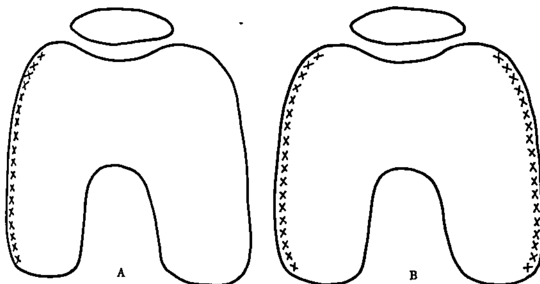


Figure 1A, 1B Schematically drawn horizontal sections of the distal femoral epiphysis at the level of the growth plates The crosses indicate the extent of the defects in each group of animals

RESULTS

Macroscopic findings

Alterations in the growth of the femurs were found in 54 of the 59 rabbits. Among the 32 in which the defect was produced on the lateral aspect of the epiphyseal growth plate, 29 showed the development of a valgus deformity which became evident at the end of the third week and was maximal 12 weeks after the procedure

When compared with the control femurs, the operated femurs were shorter (Figure 2), at 16 weeks there being an average shortening of 5.2 mm In three animals in this group there was no difference between the treated and control sides. Among the 27 rabbits in which the defect had been induced both medially and laterally, the most prominent finding was the marked shortening of the operated femurs in 25 animals, which reached an average of 8 8 mm 16 weeks after the procedure. The metaphyseal region of the operated femurs appeared to be expanded, with callus formation on the medial and lateral aspects (Figure 3) In four animals there was a valgus deformity of the distal femoral epiphysis in addition to the shortening In two animals in this group there was no difference between the treated and control sides

Microscopic findings

In both groups of rabbits the defect of the epiphyseal growth plates was found to have been replaced by bone which formed a bridge between the epiphyseal and metaphyseal parts of the femur and which resembled the callus formation seen at fracture sites (Figure 4) Evidence for the formation of these bone bridges was already found in the animals sacrificed as early as 10 days and by 3 weeks they were seen to be fully formed From 5 to 7 weeks after the procedure the epiphyseal plates were found to be narrowed and the number of cells in the cartilage columns decreased, in comparison with the control side In animals sacrificed 9 weeks or more after the operation, there was no epiphyseal cartilage on the operated side (Figure 5A) whereas on the control side it was still present, corresponding with the animal's age (Figure 5B) In some specimens there was a thin cortical plate of bone



2 Normal control femur (on left) and ' femur (on right) 16 weeks after creation ; lateral defect Operated femur shows shortening and valgus deformity



Figure 3 Normal control femur (on right) and operated femur (on left) 8 weeks after creation of medial and lateral defects Note shortening of the operated femur and callus formation on medial and lateral aspects of metaphysis

replacing the epiphyseal growth plate In the four animals that developed valgus deformities after the creation of bilateral defects, bone bridges were found only on the lateral aspect of the plate while none developed on the medial side, which had normal epiphyseal cartilage In the five animals in which there were no alterations in bone, the defects were all filled by epiphyseal cartilage and there was no difference between the histological appearance of the control and operated femurs.

X-ray findings

Roentgenological examination revealed normal trabecular structure with signs of callus formation in the treated area of the femurs.

DISCUSSION

The specific properties of the CO_2 laser beam make it a superior instrument with which to achieve a very fine incision (Kaplan & Sh[illegible] 1976 Kaplan et al. 1973). It has a wave length of 10 6 microns and emits [illegible] energy which is totally absorbed by water so that it can vaporize tissue at its focal point, [illegible] leaving the adjacent tissue [illegible] affected The thermal damage produced is [illegible] minimal and when it is used with a low power output, practically nil. Soft tissue [illegible]

be incised with a low power output of less than 10 watts while for hard tissues such as bone power output of at least 30 watts is required. Thus when a low-power laser beam is applied directly to epiphyseal cartilage it damages the cartilage selectively without affecting the adjacent bone

The experiments carried out by us showed that when part of the epiphyseal plate is destroyed by means of the CO_2 laser the normal adjacent bone acts like that at a fracture site and the defect is therefore filled by newly formed callus which replaces the growth cartilage and leads to cessation of bone growth Furthermore, a premature disappearance of the treated growth plates and subsequent bone shortening were also observed in most of the experimental animals. In explanation of the latter phenomenon, it may be assumed that the bone bridges which are firm enough so that they will not break, counteract the longitudinal traction forces exerted by cartilage columns, thus causing an opposing pressure on the growth plates Gelbke (1951) and Sijbrandij (1963) showed that pressure applied to the epiphyseal plates leads to an inhibition of growth and disappearance of the growth cartilage, observations which are compatible with the results obtained in our experiments.

In those femurs that remained unaffected by the procedure, the defects were filled by

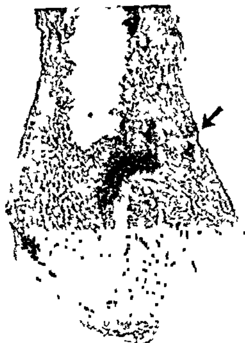


Figure 4 Histological section of distal part of the femur 3 weeks after creation of lateral defect The arrow indicates the bone bridge between the epiphyseal and metaphyseal parts of the femur

epiphyseal cartilage which apparently served as an interposing material and thus prevented the formation of a bone bridge This regeneration of the growth plates taking place before a bone bridge could be formed while still unexplained, is a phenomenon which has

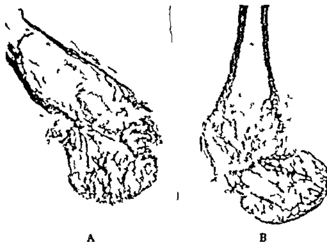


Figure 5A Histological section showing absence of epiphyseal growth plate 9 weeks after creation of lateral defect

Figure 5B Normal epiphyseal growth plate on opposite femur of the same animal

been observed by a number of authors (Langenskiöld & Edgren 1949, Heikel 1960, Österman 1972, Langenskiöld 1975)

The information provided by this study on rabbits may well prove valuable in the further development of orthopedic procedures designed to correct certain types of deformities as well as inequalities in limb length

REFERENCES

Gelbke, H (1951) The influence of pressure and tension on growing bone in experiments with animals. *J Bone Jt Surg* 33-A, 947–954

Heikel, *H V A (1960) Experimental epiphyseal* transplantation Part II Histological observations. *Acta orthop scand* 30, 1–19

Kaplan, I, Ger, R. & Sharon, U (1973) The carbon dioxide laser in plastic surgery *Brit. J plast Surg* 26, 359–362

Kaplan, I & Sharon, U (1976) Current laser surgery *Ann. N Y Acad Sci.* 267, 247-253

Langenskiöld, A. (1975) An operation for partial closure of an epiphyseal plate in children and its experimental basis. *J Bone Jt Surg* 57 B, 325–330

Langenskiöld, A. & Edgren, W (1949) Increase *of chondrodysplasia by localized roentgen ray* injury – an experimental study of bone growth *Acta chir scand 99, 353–373*

Österman, K. (1972) Operative elimination of partial premature epiphyseal closure. An experimental study *Acta orthop scand* Suppl 147

Sijbrandij S (1963) Inhibition of tibial growth by means of compression of its proximal epiphyseal disc in the rabbit. *Acta anat (Basel)* 55, 278–285

Verschueren, R C. *I, Koudstaal, I.* & Oldhoff, I (1975) The carbon dioxide laser some possibilities in surgery *Acta chir belg* 74, 197–204

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RESECTION AND RECONSTRUCTION FOR BONE TUMOURS

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For the surgical treatment of tumours in long bones a technique in which the resected bone segment is autoclaved and replaced is described.

The results in three patients who had undergone this operation 7 to 11 [illegible]

a similar way are reported from the literature

Key words autoclaved bone, bone transplant, bone tumours, dia-epiphyseal resection, knee arthrodesis

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Extensive diaphyso-epiphyseal resection is advisable for bone tumours in long bones when amputation appears to be too drastic and local excision insufficient This kind of treatment is indicated in the malignant type of giant cell tumours and in chondrosarcomas. Even in special cases of osteogenic sarcoma, local resection seems justified.

Among the many procedures that have been advocated are the insertion of a prosthesis or a massive homograft in an attempt to preserve the mobility of the joint. A hemi or total joint prosthesis is only good therapy for patients with a relatively short life expectancy, it is not an acceptable treatment for those who are at middle age or younger and need a strong leg

In this paper a description is given of three patients in whom the bone segment containing the tumour was resected Reconstruction of the continuity of the bone was achieved by replacement of the bone segment, after autoclaving, and addition of free fresh autogenous bone chips.

OPERATIVE PROCEDURE

A tourniquet is used. The tumour-bearing portion of the femur or tibia is resected to a sufficient distance on either side of the tumour so as to include healthy bone If there is destruction of the cortex of the bone by the tumour the adjoining soft tissues are taken away Also the scar of a previous biopsy is excised Next the resected bone segment is autoclaved at 120°C for 15 minutes. After this treatment the bone segment can be easily freed of soft tissues such as periosteum, parts of joint capsule and tendons and all the bone that is weakened by tumour growth.

The next step in the operation is reconstruction of the continuity of the bone. In order to arthrodese the knee the joint surfaces are sawn

KUNTSCHER NAIL

CHONDROSARCOMA

AUTOGENOUS
AUTOCLAVED GRAFT
10 cm
LENGTH

Figure 1 Diagram of the operative procedure

off. Then the autoclaved bone segment is replaced in its original bed and fixed with an extra long Kuntscher nail (Figure 1).

To stimulate union and fill the tumour cavity fresh spongy autogenous bone chips from the patella and the resected joint surfaces are used. For the same reason it is advisable to bridge the autoclaved bone segment by one or two fresh cortical tibial grafts from the opposite leg or spongeous bone chips from the ileum.

CASE REPORTS

This operative procedure was performed in [illegible] patients.

Case 1

In December 1962 a male aged 26 years was admitted to the hospital complaining of pain in his left knee. Radiological examination showed an osteolytic lesion in the proximal end of the left tibia (Figure 2).

From a biopsy specimen a chondrosarcoma of a low degree of malignancy was diagnosed. The case was sent to the Dutch Bone Tumour Committee. Following the Committee's advice resection of the proximal end of the tibia was carried out. After autoclaving of the resected segment the knee was arthrodesed as is shown in Figure 1. This operation was carried out in February 1963. For the postoperative radiographs see Figure 3. In April 1967 the Kuntscher nail was



Figure 2 Case 1 Chondrosarcoma in the upper end of the left tibia



Figure 3 Case 1 Radiographs of the left knee [illegible] months after the operation.



Figure 4 Case 1 Radiographs 1–11 years after the operation.

extracted. In the same month spontaneous fracture developed in the area of the autoclaved segment. This fracture was stabilized with a massive cortical autogenous tibial graft and six screws. The radiographs of this case in the period from 1964 till 1974 are shown in Figure 4

In July 1964 17 months after re-implantation of the autoclaved segment a specimen from this segment was taken for microscopical examination



Figure 5 Case 1 Histological pattern of the autoclaved bone 17 months after re-implantation (270×) There is necrotic bone adjacent to highly vascularized fibrous tissue and osteoid tissue



Figure 6 Case 2 Osteolytic lesion in the lower end of the femur giant cell tumour of the bone

The pathologist found necrotic bone surrounded by zones of revascularization and as yet immature osteoid tissue (Figure 5)

Case 2

In October 1966 a female aged 53 years came to the hospital complaining of pain in her left knee of 6 months duration Radiographs showed a radiolucent non trabeculated area, [illegible] in diameter, in the lower end of the left femur (Figure 6) From a microscopic examination of a



Figure 7 Case 2 Radiographs of the [illegible] months after the operation

cortical autograft The method provides a stable extremity in the uncomplicated cases within approximately 1 year

Several authors have reported transplantation of dead bone (boiled bone, os purum, decalcified bone, ashed bone and frozen bone) both in experimental and clinical research (Lloyd Roberts 1952, Ehlert 1953, Chase & Herndon 1955, Williams 1964, Wilson & Lance 1965 and Parrish 1966)

It is generally accepted that fresh autogenous bone grafts fuse more quickly than all other kinds of bone transplants. To prevent non-union it is wise to bridge a massive autoclaved bone graft with fresh autogenous grafts to initiate rapid partial fusion. Nevertheless it is necessary to establish a rigid internal fixation with long-term stability This can be realized with a long intramedullary nail and if necessary additional screws to neutralize torsional forces It guarantees the stability of the bone structures till solid fusion has occurred Boiled autografts are with regard to acceptance by the host and the period required for fusion in our opinion, comparable with grafts from the bone bank (frozen homografts) The advantages of boiled autografts are

(a) The immediate availability, which is of special importance if there is no bank bone obtainable
(b) The excellent fit of the graft which facilitates the operative procedure
(c) Extensive use of bone from donor sites is not required

REFERENCES

Abell, C. F (1966) Extrusion of femoral shaft fragment by trauma and successful replacement. *J Bone Jt Surg* 48 A 537–541

Chapchal, G (1970) *Operative treatment of bone tumours* Georg Tieme Verlag Stuttgart.

Chase, S W & Herndon C. H (1955) The fate of autogenous and homogenous bone [illegible] historical review (855 references) *J Bone Jt Surg* 37-A, 809–841

Ehlert (1953) Zur Osteosynthese [illegible] Knochensarkome *Langenbecks Arch. klin Chir* 276, 185

Enneking M D & Shirley P D (19[illegible]) [illegible] arthrodesis for malignant and [illegible] malignant lesions about the knee [illegible] intramedullary rod and local bone grafts *J Bone* [illegible]

[illegible]

cadaveric bone *J Bone Jt Surg* [illegible] 428–432.

Merle d Aubigné R (1958) Diaphyseal [illegible] resection for bone tumour at the knee. *J Bone Jt Surg* 40-B, 385

Merle d Aubigné R., Meary R & Thomine J [illegible] (1966) La resection *dans le traitement des* tumeurs des os. *Rev Chir orthop* [illegible] 305–324

Nilsonne V (1969) Homologous joint transplantation in men. *Acta orthop. scand.* 40, [illegible]

Ottolenghi C. E. (1972) Massive osteo and [illegible] articular bone grafts. *Clin. Orthop* [illegible] 156–174

Parrish, F F (1966) Treatment of bone [illegible] by total excision and replacement with [illegible] autologous and homologous grafts. *J Bone Jt Surg* 48 A 968–990

Smith S. & Simon M A. (19[illegible]) [illegible] resection for chondrosarcoma. *J Bone Jt Surg* 57 A 1097–1103

Sijbrandij S & de la Fuente A. [illegible] Multiple giant cell tumour of bone. *J Bone Jt Surg* 55 B 350–356.

Thomson, V P & Steggall, C T [illegible] Chondrosarcoma of the proximal [illegible] femur treated by resection and bone [illegible] ment A six year result. *J Bone Jt Surg* [illegible] 357–367

Volkov M (1970) Allotransplantation of [illegible] *Bone Jt Surg* 52 B 49–53

Williams, G (1964) Experiences with [illegible] cadaveric cancellous bone for [illegible] bones. *J Bone Jt Surg* 46-B [illegible]

Wilson, P D (1972) A clinical study [illegible] biomechanical behaviour of [illegible] transplants used to reconstruct [illegible] defects. *Clin. Orthop* 87, 81–109

Wilson, P D & Lance E. M (19[illegible]) [illegible] reconstruction of the [illegible] segmental resection for bone tumors *J Bone Jt Surg* 47 A, 1629

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·-Y PLASTY AS TREATMENT OF 'INGER TIP AMPUTATIONS

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V-Y plasty was performed in 28 patients who suffered from a transverse amputation of the finger tip Bilateral V-Y plasty was carried out in 16 cases and single volar V-Y plasty in 12 cases. The average follow-up period was 32 months. Six patients had postoperative complications, requiring reoperation in four patients The follow up results were satisfactory The results showed that V-Y plasty is indicated in transverse amputations through the distal one-third to one-half of the nailbed but only in patients to whom the length of the finger is of importance

Key words amputation, finger-tip, V-Y plasty

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nputation of the finger tip is a minor ·jury, but it is important because of an often ·sproportionately long period of con-·lescence Moreover, there is usually a high ·equency of late sequelae such as a feeling of ·ldness, diminished or absent sensation, ·nderness, deformed nail and joint stiffness. In traumatic finger tip amputations the ·mands of a satisfactory treatment are

The sensibility must be as normal as possible
The stump must be non-tender
The nail must not be an inconvenience
The length of the finger should be maintained if possible
The movements of the joints must be free
The cosmetic result should be satisfactory

If the bone is exposed by a transverse ·nputation of the finger tip, all these ·mands can best be met by a V-Y plasty, ·her bilateral or single volar Late results of ·Y plasties have hardly ever been elucidated ·d therefore we think that our results might · of interest.

METHOD

Digital nerve block anaesthesia is used and a small Penrose drain is applied at the base of the finger as a tourniquet. All devitalized tissue is excised and the bone is smoothed

Bilateral V-Y plasty (Kutler 1947) Two triangular flaps are developed by cutting only [illegible]

(without damaging the neurovascular supply) the two flaps can be mobilized to cover the tip of the finger The flaps are sutured together and to the remaining nail or nailbed (Figure 1B). Prior to closing the volar portion of the skin it is often necessary to remove some excess pulp

Volar V-Y plasty (Atasoy et al 1970) A triangular flap with a distal base is developed (Figure 2A). The width of the base should be the [illegible]

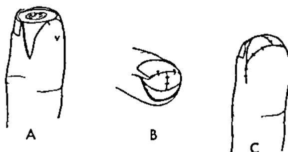


Figure 1 The operative procedure in a bilateral V Y plasty (see text for details)

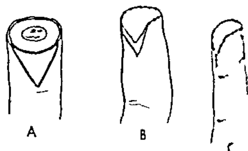


Figure 2 The operative procedure in a volar V Y plasty (see text for details)

A petrolatum mesh and sterile gauze are applied to cover the stump The finger is immobilized in a plaster of Paris cast and the hand is kept in a sling for a week.

PATIENTS

From January 1972 to December 1976 28 patients were treated with a V-Y plasty after having sustained a transverse finger tip amputation with the bone exposed. There were 24 men one woman and three children. The average age was 34 years, ranging from 2 years to 63 years. The amputations were in 16 cases caused by a sharp cutting instrument (planing machines, cutting machines, knives) and in 12 cases by a blunt injury (doors, chains, seesaws, circular saws) All except the children were treated as out-patients in digital nerve block anaesthesia. The operations were carried out by surgical house officers without special experience in hand surgery The choice between the two types of V Y plasty has rested on the discretion of the surgeon. Bilateral V-Y plasty was performed in 16 cases and volar V-Y plasty in 12 cases. All the patients had injured only a single finger V-Y plasty was performed most often on the index (13 cases) and middle (9 cases) finger

At the follow-up one patient had died and two patients refused to participate One patient later had an exarticulation at the distal interphalangeal joint due to hypersensitivity of the stump and therefore has been excluded from the late results. The evaluation has been made from case records and a personal follow-up examination. The average follow-up period was 32 months, ranging from 6 months to 57 months. The time interval until healing and the postoperative complications were based on the case records. At the follow-up the patients were asked about the period of time off work and their subjective late sequelae Tenderness was evaluated by palpation of the stump and by tapping the stump firmly on a table Light touch was tested using cotton-wool

RESULTS

Postoperative complications were seen in [illegible] patients. Five of these had infection, in [illegible] cases due to a total or partial flap necrosis. In one of these a small re-amputation was performed After healing was established another patient was re-operated due to a very localized tenderness between the two flaps and the nail and one patient had as mentioned an exarticulation in the distal interphalangeal joint due to hypersensitivity of the stump

The time interval until healing occurred and the period of time off work are listed in Table 1 There was no difference between the two groups regarding age and occupation.

None of the stumps were tender to pressure but firm tapping of the stump against a table showed tenderness in 55 per cent (Table 2). Light touch was present in all patients, but 71 per cent indicated that the feel of cotton wool was slightly abnormal compared with this sensation on other fingers (Table 3). In seven patients (32 per cent) the nail was curved, and a straight normal nail was only seen in amputations through the distal third of the nailbed. All patients had free movements of the joints.

DISCUSSION

When an evaluation of the late results of finger tip injuries is to be made one would like to base the conclusions on [illegible]

findings. However, no objective measurements or tests are available for testing the small dermal areas in a V-Y plasty

Using the two-point discrimination test abnormal values are often set at around 6 mm, but this is the same size as one side of the small triangular flaps in a bilateral V-Y plasty Therefore, a two-point discrimination test would be meaningless in as much as it is often difficult to determine the borders of the flaps.

The ninhydrin test demonstrates the sudomotor function. The tactile gnosis varies directly with the sudomotor function except in skin grafts, which regain sudomotor function after a year or so (Moberg 1958) For this reason the ninhydrin test cannot be used for an objective evaluation of the late results.

As advocated by Moberg (1958) the picking up test should be a fairly good test when applied to the thumb and the index finger and maybe the middle finger At the follow up examination this test was performed by all the patients (both with eyes open and blindfolded) The results have not

Table 1 Duration of treatment in 25 patients

Type of V Y plasty	Average period until healing	Average period off work
Bilateral	21 days (10–60)	61 days (14–180)
Volar	21 days (9–40)	29 days (14–47)
Total	21 days (9–60)	51 days (14–180)

Children and students omitted (no manual work)

Table 2 Subjective late sequelae at follow-up of 24 patients treated with V Y plasty

Type of V Y plasty	Coldness	Tenderness on percussion	Difficulty in grasping small objects	Paraesthesia	Total
Bilateral	8 57%	10 71%	6 43%	0 —	14
Volar	4 40%	4 40%	5 50%	1 10%	10
Total	12 50%	14 58%	11 46%	1 4%	24

Table 3 Objective late sequelae at follow-up of 24 patients treated with V Y plasty

Type of V Y plasty	Light touch missing	Slight hypaesthesia or dysaesthesia	Unable to differentiate pin prick and blunt	Curving of the nail	Total
Bilateral	0 —	10 71%	0 —	4 31%	14
Volar	0 —	7 70%	0 —	3 33%	10
	0 —	17 71%	0 —	7 32%	24

been listed in Table 3 as the patients often did not use the flap itself but an area immediately adjoining the flap

For these reasons one is left with a mainly subjective basis upon which the evaluation of the late results has to rest

In finger tip amputations the methods of repair include (1) conservative treatment (2) *free skin grafting (3) re amputation, (4) local* flaps and (5) pedicle flaps.

Conservative treatment should be the method of choice in finger tip amputations without exposed bone Bojsen-Møller et al (1961) found that conservative treatment gave a sensibility closer to normal and a better cosmetic result than free grafts This was confirmed by Holm & Zachariae (1974) who furthermore found a higher frequency of skin trouble and abnormal mobility in those receiving free grafts compared to the conservatively treated group In both series the period off work was a little longer in patients receiving free grafts than in those treated conservatively

Free skin grafting should accordingly only have a minor place in the treatment of finger tip amputations. Rohleder (1960) compared the late results of split skin grafts to full thickness grafts. He found no difference regarding sensibility and tenderness but the donor site on the forearm was very conspicuous in 50 per cent of cases after full-thickness grafting and only in 11 per cent after split-skin grafting

Re-amputation with removal of sufficient bone to permit soft tissue and skin closure of the stump is probably the most frequently performed operation in finger tip amputations. It should be used when an oblique stump has a ventral or lateral flap to be swung around the stump to the opposite side (Kleinert 1959). The resulting finger tip should thus have good padding and good sensibility However the stump is often annoyingly tender After re-amputation with primary closure Bojsen-Møller et al. (1961), Sturman & Duran (1963) and Holm & Zachariae (1974) *found subjective tenderness* of the stump in 36 per cent, 51 per cent and 42 per cent respectively [illegible] sensation of touch was found in 17 to 2[illegible] per cent of the cases.

Local flaps A bilateral V-Y plasty can be used in a transverse amputation of the finger tip and a volar V-Y plasty both in a transverse and an oblique dorsal amputation *of the finger tip V-Y plasties have be*[illegible] described by Kutler (1947), Fisher (19[illegible]), Atasoy et al (1970), Freiberg & Manktelow (1972) and Weston & Wallace (19[illegible]) however, the results of a late follow-up have only been reported by Freiberg & Manktelow who examined 10 patients in a series of [illegible] bilateral V-Y plasties. They found [illegible] to be present in all 10 patients and that [illegible] per cent (5/8) used the injured finger [illegible] precise tasks.

Atasoy et al (1970) reported superficial [illegible] necrosis in 4 per cent (2/56) of volar V-Y plasties, and *Freiberg & Manktelow* (19[illegible]) found postoperative complications such as flap necrosis and/or infection in 18 per cent (4/22) of bilateral V-Y plasties. In the present series there was no difference regarding postoperative complications and late results between the two types of V-Y plasties [illegible] that the average time off work was 8 7 weeks after a bilateral V-Y plasty compared with 4[illegible] weeks after a volar V-Y plasty (Table 1). The period of convalescence has not been registered in series of V-Y plasties reported earlier Barclay (1956) found that the average period off work was *9 weeks following a f*[illegible] graft and 11 5 weeks following re-amputation. The same intervals were found by [illegible] et al. (1960) to be 5 1 weeks and 6.4 weeks respectively

The outcome of the nail is determined by the level of the amputation. A [illegible] normal nail can only be expected if the amputation is through the distal third of the nailbed.

Pedicle flaps, i.e., thenar flaps and cross finger flaps are only indicated in very [illegible] volar amputations of the finger tip [illegible] exposed bone. A free graft will either [illegible] or give a poor result and a re-amputation [illegible]

mean too much of the finger length will have to be sacrificed However, pedicle flaps require a surgical expertise which only rarely will be available

Neither thenar flaps nor cross finger flaps are followed by an acceptable degree of sensibility just as there often remains permanent residual joint stiffness (Brody et al. 1960, Miller 1974). Moreover the donor area often heals unsatisfactorily as reported by Miller (1974) who found that the donor site in the palm was either keloid and puckered or rough and prominent in 63 per cent of cases

The result of the present study shows that a V-Y plasty is indicated in transverse amputations through the distal one-third to one-half of the nailbed when preserving the maximum length of the finger is important to the patient. However, the post-operative complications show that it is not an operation to be undertaken by beginners.

REFERENCES

Atasoy [illegible] 52 [illegible]

Barclay, T L (1956) The late result of finger tip injuries. *Brit J plast Surg* **8**, 38–43

Bojsen-Møller, J, Pers, M & Schmidt, A (1961) Finger tip injuries Late results. *Acta chir scand* **122**, 177–183

Brody, G S, Cloutier, A M & Woolhouse, F M (1960) The finger tip injury – an assessment of management *Plast reconstr Surg* **26**, 80–90

Fisher, R H (1967) The Kutler method of repair of finger tip amputations. *J Bone Jt Surg* **49-A**, 317–321

Freiberg, A & Manktelow, R (1972) The Kutler repair for fingertip amputations. *Plast reconstr Surg* **50**, 371–375

Holm, A & Zachariae, L (1974) Fingertip lesions an evaluation of conservative treatment versus free skin grafting *Acta orthop scand* **45**, 382–392.

Kleinert, H E (1959) Finger tip injuries and their management *Amer Surg* **25**, 41–51

Kutler, W (1947) A new method for finger tip amputation *J Amer med Ass* **133**, 29–30

Miller, A. J (1974) Single finger tip injuries treated by thenar flap *Hand* **6**, 311–314

Moberg, E (1958) Objective methods for determining the functional value of sensibility in the hand. *J Bone Jt Surg* **40-B**, 454–476

Rohleder, S (1960) Fingerendelaesioner behandlet med fri transplantation *Ugeskr Laeg* **122**, 1075–1079

Sturman, M J & Duran R J (1963) Late results of finger-tip injuries. *J Bone Jt Surg* **45-A**, 289–298

Weston P A M & Wallace, W A (1976) The use of locally based triangular flaps for the repair of finger tip injuries *Hand* **8**, 54–58

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REFERENCES

Atasoy E [illegible]

Barclay, T. L (1956) The late result of finger tip injuries. *Brit J plast Surg* 8, 38–43

Bojsen-Møller, J, Pers, M. & Schmidt, A. (1961) Finger tip injuries Late results. *Acta chir scand* 122, 177–183

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[illegible] A, 317–321

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[illegible] 382–392.

Kleinert, H E (1959) Finger tip injuries and their management. *Amer Surg* 25, 41–51

Kutler, W (1947) A new method for finger tip amputation. *J Amer med Ass* 133, 29–30

Miller, A J (1974) Single finger tip injuries treated by thenar flap *Hand* 6, 311–314

Moberg, E (1958) Objective methods for determining the functional value of sensibility in the hand. *J Bone Jt Surg* 40-B, 454–476

Rohleder, S (1960) Fingerendelaesioner behandlet med fri transplantation *Ugeskr Laeg* 122, 1075–1079

Sturman, M J & Duran, R J (1963) Late results of finger tip injuries. *J Bone Jt Surg* 45-A, 289–298

Weston P A. M & Wallace, W A (1976) The use of locally based triangular flaps for the repair of finger tip injuries. *Hand* 8, 54–58

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EARLY COMPLICATIONS OF PRIMARY SHOULDER DISLOCATIONS

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A prospective study of the complications of primary shoulder dislocation was carried out for the 3-year period 1973–1976

The clinical examination was made initially in the Casualty Departm and the patient was re-examined in the Department of Physical Medic In the evaluation special attention was given to the condition of the rota cuff the blood vessels and the motor and sensory function of the affect extremity

Sixty three out of 238 patients (26 per cent) presented with the follow complications 29 lesions of the brachial plexus, 21 of the axillary ne and 28 ruptures of the rotator cuff tendon. Complications occurred m frequently in the age group over 50 years ($P < 0\,001$) and in man labourers compared with office workers ($P < 0\,05$). If the hume remained unreduced for more than 12 hours, the frequency of complicatic increased ($P < 0\,01$).

Key words humerus shoulder dislocation, tendon injuries nerve injur

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The humeroscapular joint is the joint which most often dislocates. Although the dislocation is common, little in known of the rate of complications. Whenever there are difficulties with mobilization of the shoulder joint after the primary immobilization, one or other complication is usually responsible

Reeves (1969) verified by arthrography 27 capsular ruptures in 47 shoulder dislocations. *Most of the patients with ruptures were over* 50 years of age Ludin et al. (1975) arthrographied 12 dislocations with peripheral nerve lesions verifying four incomplete and four complete ruptures of the rotator cuff tendon London (1971) established the difficulty involved in making an early clinical diagnosis of rotator cuff rupture before the patient is able to move the shoulder He estimated the frequency of axillary nerve lesions after dislocation to be 10 per cent Assmus & Meinel (197 recorded 27 axillary nerve lesions after 10 di locations and 17 other injuries of the should girdle In three of the patients the paralys was persistent Bouretz (1974) Ghitesco et a (1975) and Malinski et al (1975) separately reported one lesion of the axillar artery in connection with reduction o shoulder dislocation Hoffheinz (197 *reported* three lesions of the axillary artery one of which was a complication of humera dislocation

The purpose of this study was to analys the early complications of primary humeral dislocation

PATIENTS AND METHODS

This study consisted of 238 primary humeral dis locations treated during the period 1 9 1973 -

31.12.1976 in the Casualty Department, Clinic of Orthopaedics and Traumatology, University Central Hospital, Helsinki, Finland. The study consisted of 133 men and 105 women.

Before reduction a routine neurological examination was performed and the radial artery of the affected extremity palpated. Often the luxation was radiologically verified.

When the diagnosis was made 5 mg of diazepam was injected intramuscularly. Usually the patient was placed prone on a couch with the affected extremity hanging free over the side of the couch. The position of the shoulder joint was adjusted with the help of cushions until a painless hanging position of the extremity was found. After about 10 minutes the relaxation of muscles around the shoulder joint was checked by the surgeon and by using painless rotatory movement with the hanging humerus the reduction of the shoulder joint was completed. Sometimes an additional intravenous injection of 5–10 mg of diazepam was needed and in this way 88.5 per cent of the dislocations were reduced without general anaesthesia.

After reduction the shoulder joint was examined radiologically. (Patients with fractures visible on routine X-ray projections were not included in this study.) The patient was then transferred to the Physical Medicine Department where the status of the shoulder joint and the neurological signs of the affected extremity were checked by the same person. After 3 weeks the shoulder joint was examined for ruptures of the rotator cuff tendon according to a scheme published in a previous study (Pasila 1965). Furthermore the deep brachial veins were palpated to exclude deep venous thrombosis.

Strength measurements were used to diagnose nerve and tendon lesions of the affected shoulder using the unaffected shoulder for comparison. Arthrography was seldom necessary. When a severely degenerated rotator cuff tendon (with connection between joint cavity and subacromial bursa) did not give rise to the clinical picture of rotator cuff rupture, the rupture diagnosis was omitted.

The results were analysed and tested by t– and chi-square tests.

RESULTS

Sixty-three out of 238 patients (26 per cent) had some kind of complication (34 men and 29 women) (Table 1). The complications were divided into nerve lesions and rotator cuff ruptures.

The neurological complications consisted of brachial plexus and axillary nerve lesions but no lesions of the suprascapular or long thoracic nerves were observed. Most complications occurred in patients over 50 years of age ($P < 0.001$). Rotator cuff ruptures were only found in patients over 50 (Table 2).

The dislocation was most common in manual labourers, the difference between manual labourers and office workers as regards complications was almost significant ($P < 0.05$). Pensioners had the highest rate of complications (Table 3).

The trauma mechanism was known in 149 dislocations, uncertain in 86 dislocations and not known in three cases. It was possible however, to partially reconstruct the mechanism of trauma in the 86 uncertain cases. Patients who had fallen from a height

Table 1 Complications in the different age groups

Age (years)	Complications		
	Female	Male	Complication/Dislocation (%)
11–20	0	2	11
21–30	2	3	11
31–40	0	2	6
41–50	0	2	13
51–60	6	8	30
61–70	12	16	50
71–80	8	1	43
81–90	1	0	25
Total	29	34	26

Table 2 Types of complications in the different age groups

Age (years)	Plexus lesion	Axillary nerve lesion	Rotator cuff rupture	Number of patients
11–20	0	2	0	2
21–30	3	2	0	5
31–40	2	0	0	2
41–50	1	2	0	2
51–60	8	5	5	14
61–70	14	4	17	28
71–80	1	5	6	9
81–90	0	1	0	1
Total	29	21	28	63

Table 3 Complications in the various social groups

Social group	Complications	Dislocations	Complication/Dislocation (%)
Student	2	14	14
Manual labourer	24	101	24
Office worker	4	48	8
Pensioner	33	74	45
Total	63	237	26

Table 4 Effect of the mechanism of trauma on the complications

Trauma mechanism	Complications	Dislocations	Complication/Dislocation (%)
[illegible]	22	96	23
[illegible] a height	7	16	44
[illegible]	10	37	27
Total	39	149	26

Table 5 Effect of the "nonreduced period" on complications

"Nonreduced period" (hours)	Complications			Complication/Dislocation (%)
	Nerve lesion	Rotator cuff rupture	Total	
< 1	16	10	24	27
1–3	16	5	15	17
3–6	6	7	10	33
6–12	3	0	3	23
12–24	4	5	7	50
> 24	5	1	4	80
Total	50	28	63	26

had the highest rate of complications (Table 4).

More than half of the dislocations were reduced within 3 hours of the accident The rate of complications increased ($P < 0.01$) if the shoulder was unreduced for longer than 12 hours (Table 5)

No deep venous thromboses in the axillary region were found The reduction of the shoulder joint did not seem to cause additional complications.

DISCUSSION

In arthrotic shoulders in patients over 50 years of age it is possible with or without arthrography to find clinically symptomless capsular ruptures (Pettersson 1942, Olsson 1953) This could be the explanation for the high frequency of capsular ruptures in Reeves' report (Reeves 1969).

London (1971) estimated the frequency of axillary nerve lesions in shoulder dislocations to be 10 per cent, corresponding to the findings in the present study Bouretz (1974), Ghitesco et al. (1975) and Malinski et al (1975) each found one case of axillary artery rupture after reduction of shoulder dislocation but this *lesion did* not exist in this study

On the other hand four similar combined lesions (rotator cuff rupture and axillary nerve lesion) reported by Ludin et al (1975) were observed in this study Furthermore two uncommon combinations were observed there were five simultaneous rotator cuff and brachial plexus lesions and six axillary nerve and brachial plexus lesions.

Reports of the occurrence of complications in the various social groups seem to be uncommon, neither were there any recent studies of the effect of the length of the 'nonreduced period" on the occurrence of complications.

Complications should be suspected in older manual labourers and when the joint has been dislocated for more than 12 hours.

REFERENCES

Assmus, H & Meinel A (1976) Schulterverletzung und Axillarparese *Hefte Unfallheilk.* 79, 183–187

Bouretz, J C (1974) Lésions vasculaires iatrogènes du membre supérieur *Rev Chir orthop* 60, Suppl II, 32–35

Ghitesco, T, Constantin, A, Condor A & Dragnea, V (1975) Thrombose de l'artere axillaire consécutive à une luxation de l'épaule Autotransplantat veineux. Guérison *Chirurgie* 101, 56–58

Hoffheinz, H J (1975) Verletzungen der Arteria axillaris bei Frakturen und Luxationen des Schulterbereiches. *Mschr Unfallheilk* 78, 129–133

London, P S (1971) Treatment and after-care for dislocation of the shoulder *Physiotherapy* 57, 2–6

Ludin, H P, Haertec, M, Meyer, R. P & Noesberger, B (1975) Die Kombination der traumatischen Ruptur der Rotatorenmanschette mit Nervenläsionen *Dtsch med Wschr* 100, 142–148

Malinski, B., Balka, I & Rykowski H (1975) Rozerwanie tetnicy pachowej podczas nastawiania zwichnietego stawu barkowego *Chir Narząd. Ruchu* XL, 4, 433–435

Olsson, O (1953) Degenerative changes of the shoulder joint and their connection with shoulder pain. *Acta chir scand, Suppl* 181

Pasila, M. (1965) Periarthritis glenohumeralis *Duodecim (Helsinki)* Suppl 44

Pettersson, G (1942) Rupture of the tendon aponeurosis of the shoulder joint in antero-inferior dislocation. *Acta chir scand*, Suppl. 77

Reeves, B (1969) Acute anterior dislocation of the shoulder *Ann roy Coll Surg Engl* 44, 255–273

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PROGRESSION OF A STRUCTURAL SCOLIOSIS DURING TREATMENT WITH GROWTH HORMONE

A Case Report

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A diagnosis of panhypopituitarism was made in an infantile male at the age of 22. Skeletal age was estimated to be 14 years. Thyroxin, corticosteroid and later testosterone was administered. Growth hormone was give initially over a period of ten weeks and later for two and a half years. Th [illegible] of grow [illegible]

than growth rate *per se*.

Key words: growth, growth hormone, panhypopituitarism, scoliosis

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A connection between the velocity of growth and the progression of structural scoliosis was demonstrated already in the beginning of the [illegible] century (Bampfield 1824). The risk of an increase of the spinal deformity is particularly high during periods of rapid growth, for instance, during the prepuberal growth spurt at the age of 11 to 13 years in girls and 13 to 15 years in boys.

This case report illustrates the connection between progression of a thoracic scoliosis and two periods of growth hormone treatment in a man with panhypopituitarism.

CASE REPORT

The patient is a male born in 1946. The family history is non-contributory. His mother had moderate hypertension and albuminuria durin pregnancy. At parturition he was born in breec presentation. Immediately after delivery he wa noted to have muscular cramps in the right arm and the right side of the face. He also developed a hematoma of the right sternocleidomastoid muscl and eventually torticollis.

In 1957 he was admitted to a pediatric depart ment and a diagnosis of pituitary nanismus was made. In 1968 he was referred to an endocrine department. At admission he had a height of 143 cm and a span of 146 cm. He weighed 31.5 kg. He appeared infantile and there were no secondary sex characteristics. The thyroid was not palpable and blood pressure was 105/80 mm Hg. He had a slight anemia, but normal serum electrolytes and normal liver and kidney function.

Thyroid function. PBI was 4.1 μg/100 ml and T_3 resin uptake 91 per cent, serum cholesterol 273 mg/100 ml. Iodine uptake increased from 26 per cent to 56 per cent after administration of thyrotropin. On scanning the thyroid gland appeared small but otherwise normal. A provisional diagnosis of secondary hypothyroidism was made and thyroxin administration was started with a

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dosage of 0 1 mg daily which was gradually increased to 0 2 mg daily This dosage was maintained throughout the reported studies.

Adrenal function. Urinary steroids and plasma cortisol were subnormal under basal conditions, but increased following ACTH No increase was demonstrable following metyrapone Following the demonstration of ACTH deficiency the patient was put on cortisone acetate perorally 5 mg twice daily This dosage was increased to 5 mg three times daily in November of 1970

Gonadal function Urinary gonadotrophins and later plasma FSH and LH determined radioimmunologically were low During the time of observation there were no spontaneous signs of puberty and in November of 1970 treatment with testosterone was started

Growth hormone Growth hormone levels were low or undetectable and did not increase in connection with insulin induced adequate hypoglycemia Growth hormone (Kabi 1620 DqP7) was administered 2 mg daily for 1 week Under metabolic ward conditions this caused a decrease of urinary nitrogen excretion from an average of 9 to an average of 4 mg daily Thereafter the same preparation was given by injections of 2 mg twice a week from September 28 to December 3 of 1968 (10 weeks).

Growth hormone therapy was resumed with the same preparation (Kabi 1620 DqP27) in February of 1970 that is after 14 months, in a dosage of 3 7 mg twice weekly and thereafter growth hormone was given continuously until September of 1972 (31 months) The dosage was increased to three injections weekly in April of 1971

CLINICAL COURSE

On admission at the age of 22 this man was severely retarded physically The skeletal age was estimated as 14 years. Standing height was 143 cm (compared with the average height of Swedish adult males of 179 cm) A structural scoliosis of 15° according to Cobb (1948) was known to have remained constant for more than 3 years.

Growth hormone therapy induced rapid growth Simultaneously, the structural scoliosis progressed from 15° to 27° over a period of 10 weeks. Because of this progression of the scoliosis, growth hormone therapy was stopped After cessation of growth hormone therapy, growth continued at a slower rate During this period of 13 months the scoliosis remained stationary

A Milwaukee brace was constructed and fitted, whereafter growth hormone therapy was resumed when the patient had been adequately braced In spite of an accelerated growth rate no change in the spinal curve could be demonstrated for 18 months, that is as long as the patient wore the brace all day and all night as recommended During the following 17 months, growth hormone therapy was continued, but the bracing was inadequate During this period the scoliosis progressed from 26° to 56° Growth hormone therapy was again stopped and longitudinal growth ceased, whereas there was a slight additional progression of the scoliosis to 62°

The total increase in standing height from 143 to 158 cm should be corrected for the spinal deformity which at the time of epiphyseal closure amounted to another 4 cm according to Lind & Bjure (1975)

DISCUSSION

The connection between progression of a thoracic scoliosis and two periods of increased growth velocity induced by treatment with growth hormone has been illustrated During the second period of treatment a Milwaukee brace, worn as recommended, seemed to be able to prevent the progression of the scoliosis. However, when the patient stopped wearing the Milwaukee brace as recommended the scoliosis progressed rapidly during continued growth hormone therapy To our knowledge there is no evidence that the stopping of bracing *per se* is followed by a progression of scoliosis and consequently we have interpreted the noted progression as a result of continued growth induced by growth hormone

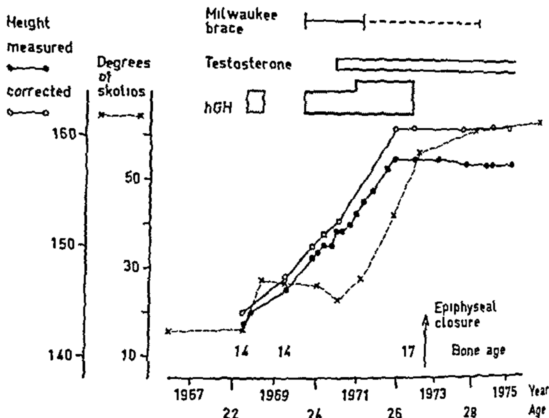


Figure 1 Longitudinal growth and progression of scoliosis in relation to therapy in a male with pan-hypopituitarism

Cortisone and thyroxin were given and there is no indication that neither of these substances influenced the clinical course Testosterone was given only during the latter part of the study, which partly coincided with the most important progression of the scoliosis There is, however, no evidence that testosterone influences the course of a scoliosis unfavorably Consequently the inadequate bracing during growth induced by the growth hormone seems to be a more probable explanation for the demonstrated progression

It is difficult to evaluate whether the progression of thoracic scoliosis was caused by the increased growth velocity as such, or by growth hormone and/or associated substances An increased serum concentration of growth hormone as well as somatomedin A has previously been demonstrated in scoliotic girls (Willner et al 1976) Girls with adolescent idiopathic scoliosis also have a different growth pattern compared with non scoliotic healthy controls The scoliotic girls have been found to be taller and slimmer at the time of diagnosis and they have grown more rapidly during the year before the diagnosis was made, compared with age-matched controls (Willner 1972, 1974) Skeletal maturation progressed at a slower rate in the scoliotic groups between the age of 13 and 18 years (Nordwall & Willner 1975)

In this patient the scoliosis was stationary for 3 years prior to treatment with growth hormone and for almost one and a half years between the two periods of growth hormone administration During both these periods growth occurred but at a slower rate Both



Figure 2 Progression of scoliosis determined on roentgenograms according to Cobb (1948)

these facts seem to imply that either growth hormone or an associated substance is the causative agent, rather than growth *per se*

REFERENCES

Bampfield, R W (1824) An essay on curvature and diseases of the spine, including all the forms of spinal distorsion. Longman, Hurst, Rees, Orme, Brown and Green London 1824 Cited by Risser, J (1964) Scoliosis past and present *J Bone Jt Surg* 46-A, 167

Cobb, J R (1948) Outline for the study of scoliosis. Instructional Course Lectures, Amer Acad. of Orthopaedics, p 261

Lindh, M & Bjure, J (1975) Lung volumes in scoliosis before and after correction by the Harrington instrumentation method. *Acta orthop scand* 46, 934

Nordwall, A & Willner S (1975) Skeletal age and height of girls with idiopathic scoliosis. *Clin. Orthop* 110, 6

Willner, S (1972) *Factors contributing to structural scoliosis* Thesis. Studentlitteratur Lund

Willner, S (1974) A study of growth in girls with adolescent idiopathic scoliosis. *Clin Orthop* 101, 129

Willner, S, Nilsson K.O Kastrup K. & Bergstrand, C.G (1976) Growth hormone and somatomedin A in girls with idiopathic scoliosis. *Acta paediat scand* 65, 547

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ANTERIOR INTERBODY LUMBAR SPINE FUSION FOR INCAPACITATING DISC DEGENERATION AND SPONDYLOLISTHESIS

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Anterior interbody lumbar spine fusion by the extraperitoneal technique was performed on 98 patients with incapacitating low back pain due to degeneration of the fourth or fifth lumbar disc (56 patients) or spondylolisthesis (42 patients) Of the discs investigated 135 proved to be degenerated, often severely, and 114 were fused. In 75 per cent of the cases no complications occurred, however, 11 patients developed thrombophlebitis, two fatal pulmonary embolism, four mild pulmonary infarcts, and three pulmonary atelectasis.

At follow-up, 3–8 years later, the fusions were solid in 91 per cent and after re-operation in 94 per cent Among the patients with spondylolisthesis the fusions were not solid in 14 per cent and among those with disc degeneration in 6 per cent. Improvement or cure was reported by 73 per cent of the patients. Thirty-one patients had constant pain. In 21 of them there was a somatic and in a few also a psychological explanation. Sixty-eight per cent were working Sixty per cent of those patients who underwent the operation after the age of 45 were receiving a disablement pension.

An attitude of reserve should be taken in operating on patients with a history of one or more operations for disc herniation, as there may be nerve root adhesions. Patients with spondylolisthesis should be followed up for at least 3 years, and if there is a suspicion of incipient pseudarthrosis they should be treated by fusion with screws through the arch defects or by classical posterior spondylodesis. The decision regarding indications for the operation and the operation itself should still be in the hands of very experienced orthopaedic surgeons, and it must be emphasized that the postoperative management, especially the prophylaxis against thrombosis, makes great demands on the staff

Key words low-back pain, low lumbar disc degeneration spondylolisthesis, lumbar interbody fusion

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Anterior interbody lumbar fusion is very seldom used in Scandinavia for the treatment of disc degeneration or spondylolisthesis, and no results of this procedure have been published in the Scandinavian medical literature. Reports in the Anglo-American literature too are scarce considering the enormous number of patients having incapacitating backache The results reported have varied within wide limits, presumably because the indications have differed Some surgeons have abandoned the method because of technical difficulties and complications, or the occurrence of pseudarthrosis.

This study has been carried out with the aim of answering the question of whether the method is worthwhile

PATIENTS AND METHODS

During the period December 1967–May 1973 we performed anterior lumbar interbody spine fusion on 98 patients (pts)

The operative indication was disabling low-back pain due to spondylolisthesis or low lumbar disc degeneration affecting one or at most two discs, the others being normal *For technical reasons, the patients'* body weight had to be within the normal range Ideally, the upper age limit should be 55 years, and the patients should be sufficiently motivated willing to work, and mentally robust

Figure 1 gives the sex ratio and age distribution The age range was 15–58, and most patients were 40–50 years of age This applies especially to the women who made up 62 per cent of the total

From Table 1 it is apparent that three-quarters of the patients had suffered from pain for at least 5 years, and one-third had had constant pain for at least 5 years In 73 per cent the pain rad a to the lower limbs. Nine had previously underg operation and 11 had been treated conservativ for lumbar disc herniation During two of t fusion operations we removed myelographical confirmed herniations from the front as there ha been little suspicion of free herniations.

Forty four pts were totally and 35 partially i capacitated In 19 the working capacity was n affected Most of the latter were younger perso

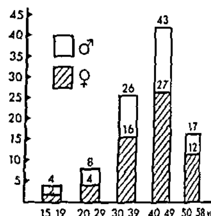


Figure 1 Age distribution and sex ratio

Table 1 Duration of pain

Length of history (years)	No of patients		No of patients with constant pain	
Less than 1	2		25	
1–4	23		41	
5–9	17	73	13	32
10–14	21		12	
More than 15	35		7	

Table 2 Lumbar discs affected and the severity of the disc changes

Disc	*37 men*	*61 women*	*Total 98 pts*	*135 discs*
LD 3	2	1	3	3
LD 4	5	4	9	9
LD 5	17	36	53	53
LD 4 + 5	15	20	35	70
Not narrowed	3	3	6	
Slightly narrowed	14	12	26	
Moderately narrowed	20	19	39	
Severely narrowed	17	47	64	

with symptoms of spondylolisthesis, and the operation was done in an endeavour to comply with their occupational wishes. Prior to the operation nine were receiving disablement pension and eight had changed to another job. Twenty-nine were doing heavy physical work, 67 light work, and seven non physical work.

Radiography showed that in the 98 patients 135 discs were affected (Table 2), usually the fourth or fifth, in 35 cases both. The third lumbar disc was affected in only three pts. Severe narrowing of the disc was present in half the men and two-thirds of the women. Sclerosing of the end plates and marginal exostoses were common findings. Among the females severe lumbo-sacral spondylosis and disc narrowing were the most common operative findings (Figure 2). Spond [illegible]

[illegible]

10–75 per cent in three (Meyerding 1956). Furthermore the vertebral body was displaced forward in relation to the overlying body in 12 of the 25 males and in 5 of the 17 females. This displacement averaged 6 mm (3–11) but fusion of the overlying disc was done in only two of the 16 pts. In all, fusion was performed on 114 discs.

Surgical technique. The patient is placed supine, with the site of fusion on a level with the peak of the kidney kink of the operating table. A paramedian longitudinal incision is made over the middle of the left rectus sheath which is opened. The rectus is loosened and pulled laterally to spare vessels and nerves. The peritoneal sac with extraperitoneal fat, containing the ureter, is gently mobilized from the inferior aspect and pushed upwards to the right, and the iliac vessels are exposed. The sacral promontory is exposed and the fifth disc located distally to the bifurcation of the aorta and vena cava. Gentle dissection is needed to avoid tearing the small vessels from the large ones. The soft tissues, with the autonomic nerves, are pushed aside and the median sacral artery may have to be ligated. The disc is kept exposed by four Steinmann pins covered with rubber drains, two above and two below the disc, as laterally as possible but without compressing the common iliac vein. The disc is opened in the middle, and stay sutures are applied to the two [illegible]

[illegible]

the end plates are chiselled off as far as the posterior limbus, as a rule to a depth of 3 cm and until the cancellous bone is normal. Suction is [illegible]

[illegible]

grafts can be calculated. A few pts develop hypotension during the lordosis positioning, and the anaesthetist should be warned that the intratracheal tube may slide down towards the carina, obstructing the main bronchus and causing atelectasis. Through a separate incision along the left iliac crest two, or in some cases three grafts are chiselled out at right angles to the crest, so

Table 3 Spondylolisthesis site, sex ratio, and grade

Grade of spondylolisthesis	I	II	III
25 men	18	6	1
17 women	8	7	2
Total 42	26	13	3
LD 3	—	1	—
LD 4	6	—	—
LD 5	20	12	3



Figure 2 X ray showing severe narrowing of the 5th lumbar disc with exostoses and sclerosing of the end plates in a woman of 50

that the grafts comprise the entire thickness of the ala Length and height have been measured beforehand. Again the patient is placed into a position of maximum lordosis, and the grafts are rammed in from the front by special rammers. During this procedure the assistant presses the overlying body backwards in cases of spondylolisthesis. When the lordosis position is

closed A vitallium plate with two screws recreates the level of the iliac crest, and above this the periosteal edges and muscular aponeuroses are firmly sutured.

Postoperatively paralytic ileus is counteracted by injections of neostigmine during the first days. *The patient is mobilized with a supporting corset* in a few days. Pts with spondylolisthesis or fusion at two levels are treated with strict bed rest for 3 months and wear a supporting corset for at least 1 year Vertebral and abdominal muscles are trained before ambulation The final follow-up examination is carried out 3 years after the operation.

Most often the fifth disc was the object of surgery (Table 4) In 16 patients the operation involved the fourth as well as fifth disc, in one patient (spondylolisthesis) only the third lumbar disc.

Complications The postoperative course was uneventful in 76 per cent. Eleven pts developed thrombophlebitis (Table 5), one has permanent oedema with a 4–5 cm increase in the circumference of the left leg and two patients have mild oedema (a 1 cm increase in circumference) Two cases of fatal pulmonary occurred, one of them about 48 hours after the operation in a patient who was otherwise in good health. The other patient had been disabled for years, bed ridden for 6 months, and had been slimming She lacked initiative, was impossible to mobilize and died 5 weeks after the operation. This patient was among our first operated cases, and with our present experience we would now consider her too great a surgical risk. Experience has taught us to expend great energy on exercises to avoid thrombosis. Four pts developed mild pulmonary infarcts, but no clinical signs of phlebitis. Three developed severe atelectasis, but with no sequelae.

Table 4 Site of spine fusion

	37 men	*61 women*	*Total 98*	
LD 3	—	1	1	
LD 4	6	6	12	
LD 5	24	45	69	
LD 4+5	7	9	16	32 (discs)
Total	44	70	114	

Table 5 Complications

	No of *pts*	Sequelae *No*	Yes
Thrombophlebitis	11	7	4
Pulmonary embolism	2	—	2 (died)
Infarct (but no phlebitis)	4	4	—
Pulmonary atelectasis	3	3	—
Pneumonia	1	1	—
Renal calculus (t.l.)	1	1	—
Neuritis of ulnar nerve due to pressure	2	2	—
Total	24	18	6
No complications	74=76%		

RESULTS

All the pts were seen at a clinical and radiological follow-up 3–8 years after the operation If there was any doubt about whether or not solid fusion had been achieved, tomography was performed Solid fusion was obtained in 86 out of 95 patients, viz , 90 5 per cent (three have died, one of them 17 months after the operation) (Figures 3 and 4) Solid union was obtained in 16 of the 17 disc spaces in which the grafts were inserted in the sagittal plane and in 85 of the 93 disc spaces in which the grafts were inserted in the frontal *plane*, i e , in 101 out of 110 disc spaces or 91 8 per cent with no difference between the two techniques of insertion Six of the 42 pts with spondylolisthesis (14 3 per cent) and three of the 53 with disc degeneration (5 7 per cent) did not show primary union. In spondylolisthesis the only stabilization is afforded by the inserted grafts. In disc



ure 3 X-ray showing solid fusion 7 years after operation on the 5th lumbar disc in a woman 6



Figure 4 Solid fusion of the 4th and 5th lumbar disc spaces 5 years after the operation in a woman of 45

eneration additional stabilization is ained by the pressure of the small joint aces against each other posteriorly Fifty- pts wore a corset for at least 1 year 19 less than 6 months.

ı nine pts solid union was not obtained three of them it was achieved by re- ration from the front (right sided roach) and in three by posterior ndylodesis (Figure 5) In one laminectomy done (nerve root irritation) and in one extra disc segment was operated on from front.

t *follow-up* one-third of the pts were free ain, one-third had constant and one-third odical pain of varying duration (Table 6) rly all the pts having constant low back wore a corset and were taking analgesics larly More than half of the total material ered from back fatigue and had to rest up everal times daily Only 27 had sciatica, ıding 25 who also had had radiating pain r to the operation. One underwent a successful Gill operation (Gill & White 1955). Eleven had minor complaints from the donor site at the iliac crest, in six of them the metal had been removed

At follow up 68 per cent were working (Table 7), but a few were receiving supplementary disablement pension A total of 29 had been referred to rehabilitation centres, half of this number having been awarded disablement pension. A total of 37 were receiving disablement pension at the time of follow up as compared with nine prior to surgery

Seventy three per cent considered themselves as cured or improved (Table 8). In 35 pts a possible somatic cause could be demonstrated as an explanation for a not completely satisfactory result, and in 24 cases psychological factors had influenced the

that the grafts comprise the entire thickness of the ala Length and height have been measured beforehand Again the patient is placed into a position of maximum lordosis, and the grafts are rammed in from the front by special rammers. During this procedure the assistant *presses the* overlying body backwards in cases of spondylolisthesis. When the lordosis position is straightened out, the two adjacent *vertebral bodies* grip around the grafts which thus become solidly fixed, their anterior edges behind the anterior edges of the vertebral bodies. The wound is closed A vitallium plate with two screws recreates the level of the iliac crest, and above this the periosteal edges and muscular aponeuroses are firmly sutured.

Postoperatively paralytic ileus is counteracted by injections of neostigmine during the first days. The patient is mobilized with a supporting corset in a few days. Pts with spondylolisthesis or fusion at two levels are treated with strict bed rest for 3 months and wear a supporting corset for at least 1 year Vertebral and abdominal muscles are trained before ambulation The final follow up examination is carried out 3 years after the operation.

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Table 7 Employment situation 3–8 years after the operation

	36 men	59 women	Total 95
Previous work resumed	19	36	55
Lighter work	8	9	17
Work later given up	4	3	7
Still working	23	42	65 (68 %)
Referred for rehabilitation	17	12	29 (14 disablement pensioners)
Disablement pension awarded	16	21	37 (before op 9 pts)

Table 8 Patients' own evaluation of the result

	36 men	59 women	Total 95	
Cured	11	12	23	73 %
Better	15	31	46	
Unchanged	9	15	24	
Worse	1	1	2	

Table 9 Possible somatic explanation of an unsatisfactory result in 31 patients having constant pain at follow-up

	No of pts
Fusion of the body 9–21 mm ventrally (spondylolisthesis)	7
Not solid fusion	5
Narrowing of other lumbar discs	4
2–4 previous operations for slipped disc (positive myelogram)	3
Subsequent slipping of overlying disc	1
Subsequent obesity (99 kg 173 cm)	1
No somatic explanation for the pain	10
Constant pain	31
Preoperative history exceeding 10 years	16
Constant pain for more than 1 year preoperatively	31
Radiation to lower limbs	30
Totally incapacitated for more than 6 months before operation	14
Has not been working after the operation	13
Referred for rehabilitation after operation	13
Disablement pension, 8 men + 11 women (before operation 0 + 5)	19

Among 31 pts having constant pain we could find a possible somatic explanation in 70 per cent (Table 9) If in spondylolisthesis the fusion is performed with the vertebral body displaced too far anteriorly, a mechanical disproportion will persist, and if the body has been displaced forward under the overlying body, there is a predisposition to disc degeneration (Figure 6) Three had already undergone at least two operations for slipped disc and two myelographies using the locally irritant contrast medium Conray® In 10 cases we found no somatic explanation for the pain, but in several cases hysterical neurosis has been diagnosed by psychiatrists

Pts with constant pain had a particularly long history of preoperative pain, and practically all of them had sciatica. Inability to work was more common in this group, and even before the operation five had been receiving disablement pension, as compared with 19 or 61 per cent at follow-up

Sixty per cent of the pts who had the operation when over the age of 45 were receiving disablement pension The spine fusion had united in all but 7 per cent.

Some but not all pts were questioned about sexual potency, and none complained of impotence

DISCUSSION

Technique Like Harmon (1963), Hodgson & Wong (1968), and Stauffer & Coventry

(1972), we used the extraperitoneal approach and did not have any difficulties or cases of paralytic ileus. The latter condition also does not seem to be a major problem in the transperitoneal technique (Sachs 1965, Debeyre & Dorat 1969, Freebody et al 1971)

Cortical grafts appear to give poorer union (Hodgson & Wong) Harmon has reported good results using sandwich grafts (cortical + cancellous bone), however, most authors use iliac grafts, as in the present series.

Harmon mobilized the pts from the day after the operation, Sachs and Stauffer & Coventry from the 3rd–4th day, Hodgson after a maximum of 14 days. Freebody et al immobilized their pts in bed for 4 weeks after fusion at one level, and cases with spondylolisthesis or multiple level fusion had 6 weeks in plaster followed by a moulded polyethylene jacket for another 3 months and thereafter an ordinary corset Debeyre & Dorat immobilized the pts in bed for 3 months. Judging by the healing results, long immobilization does not appear to have led to any notable gain

Results Harmon reported complete or partial relief of pain (clinically excellent or good results) in about 90 per cent of his 244 patients, 3–5 years after the operation The results were related to the severity and extent of the radiological changes Hodgson & Wong, Sachs, and Freebody et al have reported similar results, whereas Debeyre & Dorat obtained good results in 73 per cent Stauffer & Coventry obtained clinically satisfactory results in only 36 per cent but their material comprised many patients who were having the operation for symptoms of pseudarthrosis following posterior fusion or instability following one or more laminectomies. Hodgson & Wong reported a greater relief from pain than would have been expected judging by the radiological healing result, although they achieved radiologically solid fusion in a very high percentage of cases, especially when using iliac grafts Harmon obtained solid fusion in 95 per cent, Freebody et al in 84 per cent, and Debeyre & Dorat in 76 per cent, whereas Stauffer Coventry had solid healing in only 56 p cent of their unfavourably biased material. W obtained solid healing in 90 5 per cent, or 91 8 per cent of the fused discs, which consider satisfactory

Complications Deep vein thrombosis a other postoperative complications occurred less than 1 per cent of Harmon's patien This must be ascribed to the energetic a early mobilization, as the patients were d charged within 9 days. Hodgson & Wo encountered deep vein thrombosis in two c of 74 operated patients, Sachs in two out 50 plus two cases of non fatal pulmon embolism Freebody et al recorded 11 p cent with deep vein thrombosis and th cases of pulmonary embolism among 2 operated patients (one fatal pulmona embolus) Among 83 operated patie Stauffer & Coventry found three with de vein thrombosis and one with pulmon embolism, and Debeyre & Dorat record two cases of deep vein thrombosis among 1 patients plus two cases of pulmona embolism In our material we had two ca of fatal pulmonary embolism This may ha been a chance coincidence as the frequen of embolism in our Department is otherw very low (one in more than 1200 operatio for osteoarthrosis of the hip), but in one the cases it was due also to the indicatio for operation We would not have done th operation today on this patient We have n subsequently encountered this complication.

Cardiac arrest during the operation h been reported by Stauffer & Coventry and Freebody et al but without sequelae.

Only Stauffer & Coventry have report the occurrence of anterior displacement of th inserted grafts (one case) requiring r operation. Infection in the disc space arose two of Stauffer & Coventry's patients and one of Hodgson & Wong's

The *indications* have varied and this ha influenced the results. Stauffer & Coventry series in particular differed from those c

others because of the particularly biased material.

The reason why this operation has not gained as much ground as it deserves is, apart from anxiety due to technical problems, the difficulty and uncertainty of the task of selecting pts who can be expected to achieve a satisfactory result Harmon (1963) has demonstrated the importance of the organic changes being of sufficient severity judging by myelograms, X-ray motion films, and mature clinical consideration, as well as testing, during the operation, of the grade of disc degeneration by injecting saline solution into the disc space Candidates for this operation usually have a long history of constant pain, and this is bound to affect them psychologically, so that many of them have neurotic symptoms, possibly inveterate neurosis, which can decisively affect the result Therefore, Wilfling et al (1973) have suggested including psychological tests in the assessment. Our material confirms that mental disorders may aggravate the result, even when a definite cause of pain cannot be demonstrated clinically or radiologically Patients who have not been relieved of pain go on consulting the orthopaedic surgeon unlike those who are free of pain, and this distorts the evaluation of the results, thus influencing his future attitude to the indications. Therefore, follow-up is necessary Thereby, the result proves to be considerably better than assumed *a priori*, viz, three-quarters cured or definitely better and 68 per cent working, in a country with a highly developed social welfare service. In our opinion, this method of treatment is still justified, but its indications have now been further elucidated. In the future we shall be very restrictive in the case of patients over 45 years of age, as 60 per cent of them are awarded disablement pension after the operation. We shall try to evaluate the patients' psyche more closely before deciding upon an operation and shall exclude patients having fixed neurotic symptoms. Reserve should also be displayed in operating on patients who have previously undergone one or more operations for disc herniation, as there may be nerve root adhesions. Patients with spondylolisthesis should be followed for at least three years, and if there is the slightest suspicion of incipient pseudarthrosis posterior spondylodesis by screws through the arch defects or some other form of fixation should be performed

The decision regarding the indications for operation and the operation itself should still be in the hands of very experienced orthopaedic surgeons, and it must be emphasized that the postoperative management, especially the prevention of thrombosis, makes great demands upon the staff

REFERENCES

Debeyre, J & Dorat, J (1969) Arthrodèses intersomatiques lombosacrées. *Rev Chir orthop* 55, 499–514

Freebody, D, Bendall, R & Taylor, R D (1971) Anterior transperitoneal lumbar fusion *J Bone Jt Surg* 53-B 617–627

Gill, G G & White, H L (1965) Surgical treatment of spondylolisthesis without spine fusion. *Acta orthop scand*, Suppl. 85

Harmon, P H (1963) Anterior excision and vertebral body fusion operation for intervertebral disc syndromes of the lower lumbar spine *Clin Orthop* 26, 107–127

Hodgson A R & Wong S, K (1968) A description of a technic and evaluation of results in anterior spinal fusion for deranged intervertebral disc and spondylolisthesis. *Clin. Orthop* 56, 133–162.

Meyerding H W (1956) The spondylolisthesis. *J int Coll Surg 26, 566–591*

Sachs, S (1965) Anterior interbody fusion of the lumbar spine *J Bone Jt Surg* 47 B, 211–223

Stauffer, R. N & Coventry, M B (1972) Anterior interbody lumbar spine fusion. *J Bone Jt Surg 54-A, 756–768*

Wilfling, F J, Klonoff, H & Kokan, P (1973) Psychological, demographic and orthopaedic factors associated with prediction of outcome of spinal fusion. *Clin. Orthop* 90, 153–160

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FIXATION OF PELVIC FRACTURES AND DISLOCATIONS

An Experimental Study on the Loading of Pelvic Fractures and Sacro-Iliac Dislocations after External Compression Fixation

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A trapezoid external compression fixation frame assembled with th[e] Hoffmann instruments, was used for stabilizing experimental injuries to t[he] pelvic skeleton of ten cadaver specimens The resistance to loading in [a] position corresponding to upright standing was tested in 17 experimen[ts] and related to the calculated load *in vivo* The results indicated th[at] [illegible] compression frame well enough to permit weight bearing in the uprig[ht] standing position Bilateral injuries to the pelvic skeleton vertical [or] oblique, could not, however, be stabilized enough to resist more than [a] fraction of the normal load in the upright standing position

Key words dislocation, fracture fixation, loading, pelvic bones sacro-ili[ac] joint, stability

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The pelvis owes its stability to the circular arrangement of the individual bones forming the pelvic ring, to the strong interosseous ligaments between the sacrum and the ilium and to the pubic symphysis The vertical load on standing is taken up by the sacrum which moves and rotates downwards and forwards. Due to its wedge-shape it becomes compressed between the iliac bones Simultaneously the sacro-iliac ligaments tighten and add to the stability (Weisl 1954, Kopsch 1955, Solonen 1957, Hollinshead 1969)

The uneven articular surfaces of the sacro-iliac joint make possible an interlocking which is supposed to reinforce the stability of th[e] pelvic ring particularly when this is loaded o[n] standing (Weisl 1954)

In rupture, dislocation and/or fracture o[f] the pelvic structures the stability of the pelv[ic] ring becomes disturbed and the ultimate ai[m] in treatment is to restore the stability by a[s] accurate a consolidation of the dislocation and/or fracture as possible. This [is] particularly important in fractures of th[e] posterior, weight-bearing areas as injuries i[n] this region more often lead to persistent dis[]ability than is the case for fractures in the anterior region

Conservative measures such as bed rest slings and plaster have for a long time been the accepted mode of treatment in these fractures but recently external fixation with the use of Hoffmann instruments has been advocated (Carabalona et al. 1973, Connes 1973 Slatis & Karaharju 1975).

In an experimental study Slatis & Karaharju (1975) demonstrated that compression osteosynthesis of posterior pelvic fractures was best obtained by a trapezoid frame and bar mounted with an inclination of 70° to the long axis of the body The frame is attached to three pins inserted into each iliac wing The trapezoid compression frame offers an acceptable fixation of dislocations and fractures of the posterior parts of the pelvic ring but whether this fixation gives sufficient stability to allow weight bearing in the standing position is not known We consider this to be an important aspect as early mobilization could then be instituted with the compression frame in place We have therefore carried out an experimental study to analyse the amount of load different posterior fractures and dislocations can take after being fixed by the trapezoid compression frame

MATERIAL

Ten cadaver pelves were used (Table 1) They consisted of the pelvic ring with the fifth lumbar vertebra and had been cleaned of soft tissues excluding the ligaments. The specimens originated from patients who had died of diseases that did not involve the skeleton. In three cases, the medical records could not be obtained On naked eye examination the pelvic specimens did not disclose any signs of disease A total of 17 loading experiments were performed on the ten specimens, in which dislocations and fractures had been produced prior to loading To obtain sacro-iliac dislocations all the sacro-iliac ligaments and the symphysis were cut Fractures were produced by chiselling through the sacrum or the ilium and through the pubic rami in the desired direction (see Table 2)

Unilateral injuries

Ten loading experiments were performed in five there was a dislocation of one sacro-iliac joint and the symphysis in the other five there were fractures of the sacrum or ilium combined with fractures of the pubic rami (Table 2).

Bilateral injuries

Seven loading experiments were performed in two there were bilateral dislocations of the sacro-iliac joints and the symphys s, in three there were

Table 1 Specimens used for experimental injuries to the pelvic skeleton and subsequent external compression fixation

Specimen no.	Age	Sex	Weight, kg	Diagnosis
1	65	M	—	— —
2	66	M	74	Liver cirrhosis and acute pyelonephritis
3	67	M	69.5	Nephropathia with uraemia
4	69	M	74	Myocardial infarction
5	71	M	81	Cancer of the thyroid with metastasis of the liver and lymph nodes
6	72	F	— —	Cerebral thrombosis
7	73	F	69	— — — — — —
8	77	F	74	— — — — — —
9	77	F	67	Pulmonary embolism cancer of the uterus
10	82	M	47	Pulmonary embolism, myocardial infarction, acute pancreatitis

— — — information not available

Table 2 Experımental ınjurıes of pelvıc specımens

Unilateral ınjurıes Injury	Nos	Bılateral ınjurıes Injury	Nos
	5		2
	3		3
	1		1
	1		1

bılateral fractures of the sacrum and pubıc ramı and ın two unılateral ılıac fracture and contralateral dıslocatıon of the sacro-ılıac joınt combıned wıth fractures of the pubıc ramı or sectıoned symphysıs (Table 2)

METHODS

To achıeve stabılıty of the pelvıc gırdle an external compressıon frame assembled wıth the Hoffmann ınstruments was employed (Connes 1973) The mountıngs were anchored to the pelvıc gırdle wıth three pıns ınserted ınto each ılıac crest The parts of the pelvıc gırdle were readapted and compressıon exerted by a compressıon bar as part of a trapezoıd compressıon frame wıth the connector bars ınclıned to the long axıs of the body at 70° as descrıbed by Slatıs & Karaharju (1975)

As a preamble to the loadıng tests the co[...] pressıve force exerted by the Hoffmann [...] struments at the sıte of ınjury was measured [...] two cases wıth unılateral dıslocatıon of the sac[...] ılıac joınt and symphysıs and ın two cases w[...] unılateral fracture of the sacrum or ılıum a[...] pubıc ramı (Table 3) Small mercury filled rubb[...] balloons were ınserted between the dıslocated [...] fractured surfaces. The balloons were connected [...] a horızontal cylınder each contaınıng an ındıcat[...] pıston Compressıon of the pelvıs squeez[...] mercury ınto the cylınder and caused movement [...] the pıston, counterpressure was then exerted w[...] a movable vertıcal tube, filled wıth mercury un[...] the ındıcator mark on the pıston returned to ı[...] ınıtıal posıtıon (cf Slatıs & Karaharju 1975). Th[...] compressıon was regıstered near maxımu[...] obtaınable compressıon when the ındıvıdual com[...]ponents of the frame started bendıng

Table 3 Compression obtained with external compression fixation of injuries to the pelvic skeleton

Specimen no	Injury	Compression of the posterior arch, kPa	Compression of the anterior arch, kPa
7		146	116
8		145	117
9		4*	85
10		177	35

ation with dislocation of iliac fracture, in contact only at its lower part.

The loading experiments on the specimens, abilized by the external compression fixation, re performed in a standard material testing achine (Alwetron Model T-20(5) with a formation speed of 5 mm per minute (cf. unterberg et al. 1976). The sacral tuberosities d the inferior pubic rami of the specimens were ed in two separate blocks of epoxy resin (Plastic dding"), one for each side, in a position corresponding to upright standing (Figure 1). The d and time were registered on an x-y-recorder. e hypothetical load in upright standing was culated according to Nachemson & Elfström 970).

ESULTS

e compressive forces obtained at the site of ury in the posterior and anterior arches of the pelvic girdle are presented in Table 3. In specimen No. 9 the fracture of the ilium was not totally reduced and thus compression was only exerted on its caudal part, whence the mercury-filled balloon was twisted and not compressed.

The results of the load tests are shown in Tables 4a and 4b. Graphic recordings of load tests are shown in Figure 2.

Comments

Group 1. Specimens with unilateral dislocation of the sacroiliac joint and symphysis.

In this series a gradual dislocation of the sacroiliac joint started when approximately

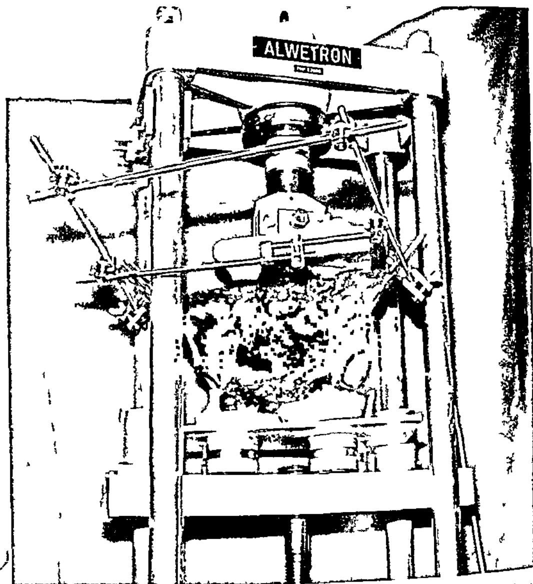


Figure 1 Specimen with the trapezoid external compression frame under load in material testing machine

one third of the ultimate acceptance of load was reached

Group 2 Specimens with unilateral fractures of the sacrum or ilium and the pubic rami

In these cases a slight gradual dislocation took place when the posterior fracture was vertical but not when the fracture was oblique In the latter case the pelvis was almost stable until the ultimate acceptance of load At this time a fracture developed on the opposite side

Group 3 Specimens with bilateral dislocation of the sacro-iliac joint and symphysis.

In these cases a gradual dislocation of the sacro-iliac joint started from the onset of loading

Group 4 Specimens with bilateral fractures of the sacrum or ilium and the pubic rami.

As in Group 2 a gradual dislocation took place during loading when the fractures were vertical Oblique fractures combined with contralateral dislocation of the sacro-iliac

'' 4a. *Results of external compression fixation of unilateral experimental injuries to the pelvic skeleton*

Specimen no	Injury	Ultimate acceptance of load, N	Calculated load in upright standing, N
1		1962	951
2		1530	1108
6		657	—
7		1207	961
8		1597	922
3		1540	1010
4		2452	1020
10		2695	624
5		2950	1020
*9		*1177*	*824*

ᵕompression only exerted on caudal part because of dislocation of the iliac fracture

did not resist loading better than
ᶦ vertical fractures.

ᵓᶦ

ᵕ of the pelvis constitute some 3 per
of all fractures. Traffic accidents and
from heights are the causative factors
' the severity of the impact is great. It has
found that 200 – 1000 kp (1962 –
) are necessary to disrupt the pelvic
(Colachis et al. 1963). When the pelvic
ᵕ becomes fractured, the loss of stability is
' if the posterior, weight-bearing
rch of the pelvic girdle is involved. The
tability can at times be equalled to flailness.

Conservative treatment by balanced traction or plaster fixation can to a certain extent reduce the fracture, but if the hemipelvis is grossly displaced, recurrent dislocation is apt to occur. Raf (1966) reported a high incidence of persistent pelvic asymmetry and low back pain at follow-up of patients with double vertical fractures.

Recent development of the armamentarium for external fixation of fractures has opened up new possibilities for the treatment of unstable pelvic fractures. Preliminary reports by Connes (1973) and Slatis & Karaharju (1975) indicate that external fixation of the pelvis not only stabilizes the fracture but also provides a great relief from pain.

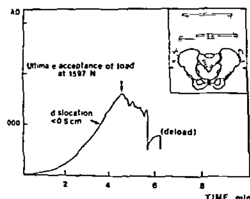
Table 4b Results of external compression fixation of bilateral experimental injuries to the pelvic skeleton

Specimen no	Injury	Ultimate acceptance of load, N	Calculated load in upright standing N
6 7		50 102	— 961
3 4 10		118 353 471	1010 1020 624
8		422	922
9		216	824

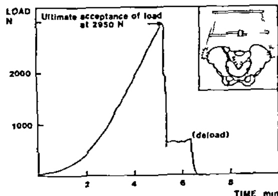
injured area Based upon clinical experience, the time of recumbency advocated after external fixation of the fracture has been 3 weeks, but so far no firm evidence regarding the load acceptance of different pelvic injuries treated by external fixation has been available

The experimental data obtained in the present investigation show that the external trapezoid compression frame stabilizes the pelvic girdle so that it can resist vertical load forces on the sacrum surprisingly well The load tolerance is, however, closely related to the type of skeletal injury present It is the unilateral injuries which can best resist vertical loading after compression fixation A fracture through the sacrum or the ilium is more stable than a dislocation through the sacro-iliac joint Furthermore an oblique fracture through th posterior arch is more stable than a vertica one The reason for this can be found in th articular surfaces of the sacro iliac joint whic are slippery and difficult to reduce into locked position The rugged surfaces o fractures appear to have better interlockin properties Bilateral injuries, in which th hemipelvis is detached from the sacrum o both sides, remain – as may be expected unstable for vertical load despite the compres sion device The frame is here merel maintaining the position of the reduced part of the pelvis.

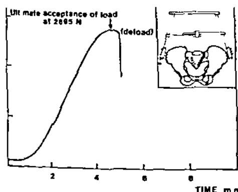
The body weight was known in eight of th ten cases for this investigation making i possible to calculate the normal load on th L V vertebra in the upright standing positio



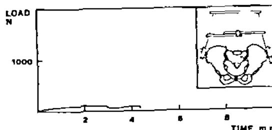
Specimen no 8 The calculated normal load in nding position was 922N



C Specimen no 5 The calculated normal load in the upright standing position was 1020N



Specimen no 10 The calculated normal load the upright standing position was 624N



D Specimen no 6 The normal load could not be calculated but without doubt far exceeded this very low acceptance of load

Figure 2 Load time diagrams for pelvic specimens with different types of injury (see insets)

achemson & Elfström 1970) It has been that the load varies depending on movements, etc. On slow walking the ad increased by about 15 per cent and on mping by 40 per cent and finally on straining erect posture by about 50 per cent

Our method of supporting the loaded ves by separate blocks of epoxy resin has practical reasons not been quite ysiological as the load is normally taken up the hip joints. The results mainly give an dication of the resistance to loading when a has been applied to an ex- pelvis.

In the present series, the ultimate load in unilateral lesions well surpassed the calculated values for vertical load on the pelvis during physiological conditions In bilateral lesions, on the contrary, the resistance to vertical load was far below the calculated load in the erect position These findings suggest that in unilateral lesions partial or full weight bearing may be instituted immediately after application of the frame, whereas in bilateral lesions weight-bearing should be postponed for several weeks In these experiments the stabilizing effect of muscular activity and the possibility of partly intact sacro-iliac ligaments in pelvic disruptions *in vivo* have not been given due consideration

Hence, correlations with clinical conditions

should be made with due caution On the other hand calculations regarding the physiological load in the upright position and the data obtained warrant certain conclusions which are applicable to clinical conditions Thus in lesions of the posterior and anterior arch of the pelvis, properly reduced and stabilized with the trapezoid compression frame it may be suggested

that in bilateral injuries no weight bearing should be permitted before the already suggested 3 weeks of immobilization

that the above recommendation also includes unilateral sacro-iliac dislocations and unilateral vertical fracture of the sacrum or iliac wing weight bearing by crutches is possible

that in unilateral injury involving oblique fracture of the sacrum or iliac wing early mobilization with full weight bearing may be instituted

REFERENCES

Carabalona P *Rabichong* P *Bonnel* F Perruchon E & Peguret F (1973) Apports du fixateur externe dans les disjonct ons du pub et de l articulation sacro-iliaque *Montpellu chir* 29, 61 70

Colachis, Jr S C Worden, R. E. Bech ol, C. O Strohm B R (1963) Movement of t sacroiliac joint in the adult male a prelimina report *Arch phys Med* 44 490–498

Connes, H (1973) *Hoffmann s double fra external anchorage* Geat Paris.

Gunterberg B Romanus, B & S ener B (19 Pelvic strength after major amputation of t sacrum *An experimental study Acta orth scand* 47, 635 642

Naci en so i, A & La u *dynamic pressure measurements in lumb discs* Almqvist & Wiksell, Stockholm

Raf L (1966) Double vertical fractures of t pelvis. *Acta chir scand* 131 298 305

Slat s, P & Karaharju, E O (1975) Exter *fixation of the pelvic* girdle with a trapezo compress on frame *Injury* 7, 53 56.

Solonen K A (1957) The sacroil ac join in t light of anatomical roentgenolog cal and clinic studies *Acta orthop scand* Suppl 27 1 1

We sl H (1954) The articular surfaces of t sacro-il ac joint and their relation to t *movements* of the sacrum *Acta anat.* (Bas 22, 1 14

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ERYTHROCYTE SEDIMENTATION RATE IN INFECTED AND NON-INFECTED TOTAL HIP ARTHROPLASTIES

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The postoperative course of the erythrocyte sedimentation rate (ESR) following total hip replacement was studied in 18 patients with delayed infections and compared with the course in 75 uncomplicated cases. Normally, the ESR returned to the preoperative level in 3–6 months, but in delayed infections it was significantly increased already during the first postoperative months, and never returned to normal levels. There was also a small but significant difference between the preoperative values in the two groups, which in women may be explained by a pre-existing infection in the hip

Key words hip, arthroplasty, infection, erythrocyte sedimentation rate

Accepted 27.xii 77

The early wound infections following total joint replacement cause the same local and systemic symptoms and signs as other wound infections during or shortly after the wound-healing stage, and are therefore unlikely to be overlooked On the other hand, delayed infections that give symptoms months or years after the operation may be difficult to detect The erythrocyte sedimentation rate (ESR) seems, in this respect, to be a simple and valuable asset (Carlsson et al 1977, Mulier et al. 1973, Reichelt & Brand 1974)

Since total hip arthroplasty was introduced into the Department of Orthopedic Surgery at Malmö General Hospital in 1968, measurement of ESR has become a routine procedure in the laboratory investigation of all patients operated upon and at every visit to the out-patient clinic.

This investigation describes the normal course of the ESR after uncomplicated total hip replacements, and compares it with the course in patients with a normal early postoperative wound healing but who subsequently prove to have a delayed infection

Financial support was obtained from the Swedish Medical Research Council (project no. B 77-17X-2737-09B)

MATERIAL AND METHODS

The ESR was performed by the Westergren method Böttiger & Svedberg (1967) suggested the following normal ranges (mean ± 2 s.d.)

	Men	Women
< 50 years	0–13	0–21 mm
> 50 years	0–19	0–28 mm

The material consisted of two groups of patients. In both groups, patients with rheumatoid arthritis, pelvospondylitis or with any other known cause of an elevated ESR were excluded

Group A

Seventy-five patients, 51 females and 24 males, underwent total hip replacement, according to Charnley at the Malmo General Hospital. The ages of the females ranged from 42 to 79 years (mean 65 years) Only two women were less than 50 years old—42 and 48 years, respectively The

should be made with due caution On the other hand, calculations regarding the physiological load in the upright position and the data obtained warrant certain conclusions which are applicable to clinical conditions Thus in lesions of the posterior and anterior arch of the pelvis properly reduced and stabilized with the trapezoid compression frame it may be suggested

that in bilateral injuries no weight-bearing should be permitted before the already suggested 3 weeks of immobilization

that the above recommendation also includes unilateral sacro-iliac dislocations and unilateral vertical fracture of the sacrum or iliac wing weight bearing by crutches is possible,

that in unilateral injury involving oblique fracture of the sacrum or iliac wing early mobilization with full weight bearing may be instituted

REFERENCES

Carabalona P Rabichong P Bonnel, F, Perruchon E & Peguret F (1973) Apports du fixateur externe dans les disjonctions du pubis et de l articulation sacro-iliaque *Montpellier chir* 29, 61–70

Colachis, Jr S C Worden R. E., Bechtol, C.O & Strohm B R (1963) Movement of the sacroiliac joint in the adult male a preliminary report *Arch phys Med* 44 490–498

Connes, H (1973) *Hoffmann s double frame external anchorage* Gead Paris.

Gunterberg B Romanus, B & Stener B (19 Pelvic strength after major amputation of sacrum An experimental study *Acta orth scand* 47, 635–642

Hollinshead, W H (1969) *Functional anatomy the limb and back* 3rd ed. pp 245 249 W Saunders Company Philadelphia

Kopsch F (1955) *Rauber Kopsch Lehrbuch Atlas der Anatomie des Menschen* Vol. 1 ed Georg Thieme Verlag Stuttgart

Nachemson, A & Elfstrom G (1970) *Intra dynamic pressure measurements in lu discs* Almqvist & Wiksell Stockholm

Råf L (1966) Double vertical fractures of pelvis. *Acta chir scand* 131, 298–305

Slätis, P & Karaharju, E O (1975) E fixation of the pelvic girdle with a tra compression frame *Injury* 7, 53 56.

Solonen K A (1957) The sacroiliac joint light of anatomical roentgenological and studies. *Acta orthop scand*, Suppl 27

Weisl H. (1954) The articular surfaces sacro-iliac joint and their relation movements of the sacrum *Acta anat.* 22, 1–14

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symptomatology it should be possible to differentiate them from delayed infections Furthermore, the inflammatory reaction caused by surgery should have disappeared and the ESR returned to normal when a joint is hit by a hematogenous infection a reasonably long time after the operation Ahlberg et al, in press) On the other hand, if the bacteria are implanted at the operation, there should be some signs of inflammation from the outset that do not disappear until treatment is instituted

In 14 patients with "late" infections following total hip replacement, Reichelt & Brand (1975) not only observed a significantly elevated ESR already from the first postoperative month, but also that the ESR never returned to normal Seeing that the same phenomenon was found in the present investigation, there is strong evidence that delayed infections are caused by bacteria implanted in the wound at operation

The evaluation of an ESR necessitates a knowledge of its course following uncomplicated total hip replacements (a factor that seems to be of special importance during the first postoperative year)

The investigation of Reichelt & Brand (1975) showed that all males had an ESR below 20 mm, 93 per cent of the females an ESR below 30 mm and 100 per cent of the females an ESR below 40 mm, 6–12 months postoperatively in uncomplicated total hip replacements. In 147 uncomplicated total hip replacements, Mulier et al. (1973) found that within 4 months the ESR normalized in 93 per cent. In the remaining 7 per cent, the ESR normalized within 1 year postoperatively

From the present investigation one can conclude (Figure 1) that an ESR of 40 mm or more, more than 3 months postoperatively strongly indicates a deep infection even if the patient is still free from symptoms, and radiographic signs of infection are absent The statement only holds true when other diseases with elevated ESR and complications such as urinary tract infection or pneumonia are excluded.

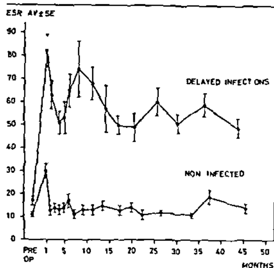


Figure 1 The course of the ESR ± SE in uncomplicated total hip arthroplasties compared with its course in delayed infections

The ESR was not checked until 1 month postoperatively During the first 2 or 3 weeks, the level is not only influenced by the surgical trauma or by infection but also by other treatments, e g, Dextran 70 infusions (Arthurson & Wallenius 1964, Rø & Kluge 1971)

The preoperative ESR must also be considered In this investigation no patient in the non-infected group had an ESR of more than 15 mm above the preoperative value 6 months postoperatively—the highest value being 34 mm. The ESR was also determined 2–3 months postoperatively in 58 of the 75 non-infected cases. At no stage did it exceed the preoperative value by more than 21 mm.

The difference between the preoperative values in the infected and non infected group is remarkable In females, but not in males, this difference may be explained by a pre-existing low-grade infection contracted at a previous operation. Thus, in males a higher ESR, even within the normal limits, for no understandable reason coincides with a higher rate of infection.

With a knowledge of the normal course of the ESR following total joint arthroplasty, it

should be possible to diagnose the infection at an earlier stage However, it is still necessary for 2 to 3 years to elapse after surgery before statements concerning the incidence of infection are made One reason for this is that most hematogenous infections occur at a late stage (Ahlberg et al. in press) Another reason is that in rheumatoid arthritis and other conditions with elevated ESR, the evaluation of the actual ESR is difficult, necessitating a reliance on other diagnostic methods such as radiography and scintigraphy

Every patient in group B experienced pain, but the time of onset, average 10 months, must be considered uncertain, seeing that the debut is seldom, if ever, acute On the contrary, in most cases slowly increasing pain in the thigh or groin is the first sign Furthermore, one gets the impression that many patients with delayed infection never become completely symptom-free postoperatively, and, indeed, some never manage to walk without a stick.

A definite correlation betweeen elevated ESR and postoperative pain was found by Mulier et al (1973)

ESR is a simple and reliable laboratory method As an elevated ESR may be the first sign of an infection, it is recommended that the method be included in the routine procedures at every examination of a patient undergoing total joint replacement

REFERENCES

Ahlberg, Å., Carlsson, Å. S & Lindberg Hematogenous infection in total joint repa ment. *Clin. Orthop* (In press)

Arthurson, G & Wallenius, G (1964) The travascular persistence of dextran of diff molecular sizes in normal humans. *Scand. clin Lab Invest* 16, 76–80

Buchholz H W & Gartman, H D (19 Infektionsprofylaxe und operative Behandl der schleichenden tiefen Infektion bei totalen Endoprothese. *Chirurg* 43, 446–453

Böttiger, L. E & Svedberg C A (1967) Nor erythrocyte sedimentation rate and age. *B med J* 2, 85–87

Carlsson, Å S, Lidgren L & Lindberg L (19 Prophylactic antibiotics against early and l deep infections after total hip replaceme *Acta orthop scand* 48, 405–410

Charnley, J (1972) Postoperative infection a total hip replacement with special referenc air contamination in the operating room. C *Orthop* 87, 167–187

Mulier, J C, Desmet, L., Martens, M Hoogmartens, M (1973) The value of clin data and laboratory findings to predict " grade" infections of total hip replaceme *Arthroplasty of the hip* ed Chapchal Ge pp 201–206 George Thieme Publishers

[illegible]

Huftgelenkes. *Z Orthop* 113, 900–90

Rø, J S & Kluge T (1971) Increased erythro sedimentation rate following anti-thromb treatment with dextran *Scand J tho cardiovasc Surg* 5, 47–50

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LATERAL DISLOCATION OF THE PATELLA FOLLOWING MARMOR AND GUEPAR ARTHROPLASTY OF THE KNEE

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The follow up of 50 knees treated with the modular Marmor prosthesis and 50 with the Guepar hinge joint included tangential radiography of the femoro-patellar joint. After Marmor arthroplasty lateral patellar dislocation was found in seven knees, in six causing pain. After Guepar arthroplasty lateral patellar dislocation was found in 32 knees, but pain was present in only three There was only a questionable correlation between pre-existing valgus deformity and postoperative lateral patellar dislocation, and an external rotation deformity of the lower leg was found in only five cases after Guepar arthroplasty Thus, neither phenomenon could explain the high incidence of lateral patellar dislocation in the Guepar series These dislocations must be assumed to be due to the unphysiological strain on the extensor apparatus inherent in this type of prosthesis.

Key words knee, arthroplasty, patella, dislocation

Accepted 21 1 78

Dysfunction of the femoro-patellar joint is now assumed to be the most common cause of poor primary results following arthroplasty of the knee (Deburge & Guepar 1976, Engelbrecht et al 1976, Insall et al 1976, Marmor 1976) Some of these poor results appear to be due to dislocation of the patella, but the *incidence* of this complication is still largely unknown and apparently depends to some extent upon the type of knee prosthesis.

The object of the present study was to elucidate the incidence of femoro-patellar dislocation, and the associated pain, following knee arthroplasty using the Marmor modular prosthesis and the Guepar hinge joint

MATERIALS AND METHODS

The material comprises 100 knee arthroplasties, 50 by the Marmor and 50 by the Guepar method, performed in the Department of Orthopaedic Surgery U, Rigshospitalet, University of Copenhagen, during the period 1974 to 1977

During the study period the two types of arthroplasty were used as complementary methods. In cases of less severe articular destruction the Marmor knee was used, in cases of advanced destruction with severe contracture or deformity the Guepar knee was preferred.

In both methods the technique of opening and closing the knee was in principle the same The approach was in all cases via a long straight, medial parapatellar incision, extending proximally into the quadriceps aponeurosis close to its

Table 1 Grading of the lateral patellar dislocation

Grade	Patellar dislocation
0	None
1	< ½ patellar width
2	½–1 patellar width
3	> 1 patellar width

junction to the vastus medialis. In all cases of rheumatoid arthritis, synovectomy was carried out. In closing the wound, the quadriceps aponeurosis and joint capsule were carefully sutured using non-absorbable knotted sutures. Postoperative mobility training was started on the 1st day, and walking with full weight-bearing began on the 10th day

Out of 50 consecutive Marmor arthroplasties 13 were performed on men and 37 on women. The age range was 18 to 82 years, mean 61 The underlying disease was rheumatoid arthritis in 29

mean 14 months.

Of the 50 consecutive Guepar arthroplasties 18 were performed on men and 32 on women The age range was 28 to 86, mean 65 years. The underlying disease was rheumatoid arthritis in 37 cases, osteoarthrosis in 10, and posttraumatic arthrosis in three. The patients had been followed up for 3 to 25 months, mean 10 months.

In all cases the follow-up included radiological examination with tangential exposure of the femoro-patellar joint. Displacement of the patella, *if present, was graded on a scale from 0 to 3* (Table 1). A direct comparison with the preoperative X-ray appearances was not possible as far as the tangential view was concerned, as this was not a routine procedure at the beginning of the period under study

RESULTS

*Following Marmor arthroplasty patellar dis*location was found in seven knees, grade I in six and grade II in one However, in the latter case the dislocation *had* been present *also* preoperatively, but no attempt had been made to correct it because of severe dysplasia of the femoro-patellar joint Thus, *following* 50 Marmor replacements there were six patellar

Table 2 Grade of lateral patellar dislocation in relation to pain in 50 knees treated with the Marmor prosthesis

Grade of dislocation	Pain			Total
	None or negligible	Moderate	Severe	
0	33	9	1	43
1	1	5	0	6
2	0	1	0	1
3	0	0	0	0
Total	34	15	1	50

Table 3 Grade of lateral patellar dislocation in relation to pain in 50 knees treated with the Guepar prosthesis

Grade of dislocation	Pain			Total
	None or negligible	Moderate	Severe	
0	18	0	0	18
1	12	0	1	13
2	12	0	2	14
3	5	0	0	5
Total	47	0	3	50

dislocations (12 per cent) which could b related to the surgical treatment. Dislocatio related to pain is shown in Table 2 Pain wa present in six out of seven knees with patella dislocation but in only 10 of the remaining 4 that did not have dislocation.

After Guepar replacement patellar dis location was found in 32 (64 per cent) out o 50 knees. Among these dislocations 13 we grade I, 14 grade II, and five grade II Within the Guepar series there was n recognized case of preoperative patellar dis location. Dislocation related to pain is show in Table 3 Pain was present in three of th 32 knees with patellar dislocation, but in non of the remaining 18 without dislocation.

The difference in the incidence of late patellar dislocation between knees bearing

Marmor (12 per cent) and Guepar (64 per cent) arthroplasty is statistically significant ($P<0.025$).

DISCUSSION

The Marmor and the Guepar series do not differ essentially in sex ratio, age distribution, underlying disease, follow-up period, surgical approach, or postoperative management On he other hand, they differ in two other respects The Guepar series comprises cases laving relatively severe destruction of the oint (cf the indications), and the two types of prosthesis are entirely different in their tion to the biomechanics of the femoro-patellar joint

The relatively severe articular destruction, n particular the presence of pronounced pre-operative valgus deformity, might be magined to be responsible for the high ncidence of patellar dislocation in the Guepar eries. It has been reported that knees with ere valgus deformity of long standing may evelop lateral patellar dislocation following urgical correction of the deformity owing to taut lateral retinaculum (Weckström et al 976) In order to elucidate this aspect, the e of dislocation is related to the presence f preoperative valgus deformity in Table 4

Table 4 Preoperative valgus deformity of the knee in relation to type of arthroplasty and to the incidence of lateral dislocation of the patella at follow-up

	Degrees of valgus deformity			Total
	0–5	10–15	>15	
Marmor				
Patella *in situ*	23	16	4	43
Patella dislocated	2	4	1	7
Guepar				
Patella *in situ*	13	4	1	18
Patella dislocated	18	6	8	32
Total	56	30	14	100

It will be seen that although the incidence of dislocation was indeed somewhat higher after correction of severe valgus deformities, lateral dislocation of the patella was almost as high among knees without valgus angulation as in the Guepar series as a whole Thus, pre-existing valgus deformity did not essentially influence the postoperative incidence of dislocation

If the Guepar prosthesis is inserted in cases with an external rotation deformity of the lower leg there will be an increased tendency for lateral dislocation in relation to the lateral displacement of the insertion of the patellar ligament The present series included five cases with such a deformity ranging from 20° to 30° Only three of them developed lateral patellar dislocation Therefore, external rotation deformity of the lower leg cannot have markedly influenced the incidence of dislocation in the Guepar series

The weakening of the vastus medialis involved by the medial parapatellar approach has possibly been the cause of the relatively few and slight dislocations in the Marmor series Since, however, this factor is the same in the Marmor and in the Guepar series, it cannot *per se* be an explanation of the increased incidence of dislocations among the Guepar operated patients.

Weckström et al (1976) and Deburge & C[illegible] (1976) [illegible]
o[illegible]
G[illegible]
is an unphysiological design of the femoral shield of the prosthesis which does not sufficiently support the lateral articular surface of the patella (Figure 1) Moreover, the shield causes a slight forward displacement of the patella Combined with the fact that the axis of flexion in the Guepar prosthesis is localized rather far posteriorly, this means great stress upon the extensor apparatus during flexion of the knee

Patellar dislocation following Guepar arthroplasty does not seem to give rise to major pain in the short term (cf Table 3). This must be due to the mechanical function of the femoral shield which secures a



Figure 1 Tangential view of the femoro-patellar joint following Guepar arthroplasty Note the un physiological shape of the femoral shield and the lateral patellar dislocation typical of the Guepar prosthesis



Figure 2 Tangential view of the femoro-patell joint 8 months after Guepar arthroplasty N the lateral patellar dislocation and severe ero of the patellar joint surface The patient h satisfactory articular function and no pain.

reasonable sliding function regardless of appreciable incongruence against the articular surface of the patella and regardless of an occasionally severe secondary malformation of the patella (Figure 2) This is unlike the findings after Marmor arthroplasty in which even rather minor dislocation of the femoro-patellar joint, with which the arthroplasty does not otherwise interfere, apparently cause pain in most cases (cf Table 2)

Patellar dislocation is not always recognized by conventional clinical and radiological examination, and often it is demonstrable only on a tangential view of the femoro-patellar joint. Therefore, patellar dislocation should be considered as a possible cause of persistent pain in the knee following arthroplasty

REFERENCES

Deburge A. & Guepar (1976) Guepar hinge pr thesis. Complications and results with t year's follow up *Clin Orthop* 120 47 53

Engelbrecht, E, Siegel, A. Rottger J Buchholz H W (1976) Statistics of total k replacement Partial and total knee repla ment, design St. Georg *Clin. Orthop* 12 54–64

Insall, J N Ranawat, C S. Aglietti, P & Sh J (1976) A comparison of four models of to knee replacement prosthesis. *J Bone Jt Sr* 58-A, 754–765

Marmor, L. (1976) The modular (Marmor) kn *Clin. Orthop* 120 86–94

Weckstrom, J., James, U & Svensson, B (19 Femuro-patellarleden efter plastik med Guep protes. *Svenska Läk. Rikstamma* p 394

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ADIOLOGICAL DIAGNOSIS OF LATERAL LIGAMENT ES'ON OF THE ANKLE

Comparison Between Talar Tilt and Anterior Sign

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In a prospective study of 244 patients with ankle lesions a comparison between the talar tilt and the anterior drawer sign was made, leading to the following conclusions

Ligament lesions which are not disclosed by the talar tilt examination may be diagnosed by the anterior drawer sign The anterior drawer sign cannot ... or vice versa The two methods are com- ... on of the ... lofibular

Key words ankle joint, anterior drawer sign, ligament injuries, talar tilt

Accepted 17 1.78

ruptures of the lateral ligaments of the are best diagnosed by arthrography et al. 1965, Fulp 1973) However, method is not generally accepted. In departments, ligament lesions of the are diagnosed by the instability of the alus – the talar tilt – provoked by forced ion of the foot (Rubin & Witten 1960, 1965)

During the last few years some authors ve recommended examination of the instability of the ankle – the anterior sign – for the diagnosis of such (Castaing & Delplace 1972, Larsen 970, Lindstrand & Mortensson 1976)

In order to compare these two methods – talar tilt and the anterior drawer sign – a investigation was made in an o answer the following questions

Can the anterior drawer sign disclose lesions which are not revealed by the talar tilt, or *vice versa* ?

2. Can the anterior drawer sign replace the talar tilt as a means of diagnosis?

3 It it possible to differentiate between an isolated lesion of the anterior talofibular ligament and a combined lesion of the anterior talofibular and the calcaneofibular ligaments by the two methods?

MATERIAL AND METHODS

The series studied consisted of 244 patients with recent ankle injury All the patients were seen within 24 hours of the trauma. In all cases a lateral ligament lesion was suspected clinically None of the patients showed radiological signs of a fracture. Radiological measurements of the talar tilt (TT) and the anterior drawer sign (ADS) were made in all cases.

Throughout the period concerned both examinations were performed using the same



Figure 1 The difference in the distance between the articular surfaces of the talus and the tibia at the le of the top of the lateral trochlea tali on the injured (left) and on the normal (right) side

technique The TT examination was performed with the investigator placed on the contralateral side of the foot to be examined With the left/right hand fixing the leg just above the ankle and the right/left hand fixing the heel, the foot was supinated with maximal force An anteroposterior exposure, centred on the middle of the ankle joint, was made on both sides, the unaffected foot always being examined before the injured one The distance between the articular surfaces of the talus and the tibia was measured at the level of the top of the lateral trochlea tali on the exposures of the injured and the unaffected sides (Figures 1 and 2) and the difference in the tilted position on the two sides was calculated

The ADS examination was performed with the leg elevated, supported at the popliteal fossa and the heel, in such a position that the thigh was horizontal, and the foot rotated 30° medially (The support at the popliteal fossa is very important, otherwise the weight of the leg alone may provoke a subluxation in the ankle joint) With the beam placed horizontally, an X-ray exposure, centred just above the tip of the malleolus, was

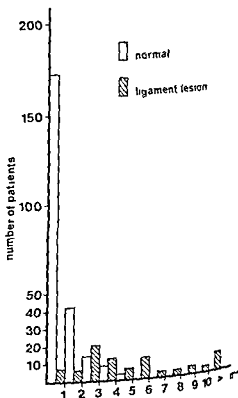


Figure 2 The difference in the distance between the articular surfaces at the level of the top of the lateral trochlea tali at rest and in forced supination in 244 normal ankles and in 85 ankles with surgically verified ligament lesions

Figure 3 Double exposures showing the position of the posterior margin of the tibia and of the posterior process of the talus before and after loading on the injured (left) and normal (right) side

made After this, the leg was loaded with a 5 kg weight just above the ankle joint, and after the patient had relaxed completely, a new X ray exposure was made on the same film with the X-ray equipment and the foot in exactly the same position. Both feet were examined, the unaffected always before the affected one The displacement of the posterior margin of the tibia in relation to that of the posterior process of the talus between the two exposures was measured on the injured and unaffected sides (Figures 3 and 4) and the difference in displacement on the two sides was calculated.

Radiologically, a diagnosis of ligament rupture was made when the difference between the injured and the unaffected sides was 3 mm or more according to the TT examination and/or when the difference in displacement on the two sides was 2 mm or more according to the ADS examination.

In the event of a positive finding the patient was usually subjected to operation with the aim of suturing the ruptured ligaments. Patients with pronounced discrepancy between the clinical and radiological findings were referred to the out-patient department If ligament rupture was still suspected after re-examination about 1 week after the trauma, these patients were treated with a plaster cast. Patients with normal radiological findings and without definite clinical suspicion of ligament rupture were regarded as having a simple sprain and were discharged immediately

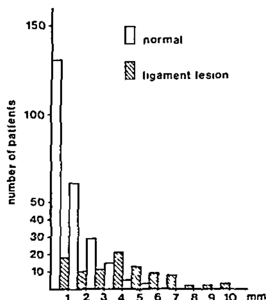


Figure 4 The displacement of the posterior margin [illegible]

with surgically verified ligament lesions

In the period from Oct 1 to Nov 30, 1976, all the examinations were assessed and almost invariably performed by the same investigator In the few cases where this was not possible, the TT examination was performed by a doctor from the emergency ward, while the ADS examination was performed by an X-ray technician In this period, doubtful cases and technical problems were often discussed with the staff In the period from Dec. 1, 1976 to Feb 15, 1977, the examinations and assessments were made routinely In this period, the TT examinations were performed by doctors from the emergency ward and the ADS examinations by X-ray technicians, while doctors from the X-ray department assessed the findings

In the final analysis of the series all X-ray films were reappraised and all hospital records were reviewed as regards symptoms, clinical and operative findings.

RESULTS

Ninety-six patients were discharged immediately with simple sprain None of these patients showed signs of ligament rupture on TT examination In three cases, a rupture of the ligaments was suspected on ADS (difference in displacement 2 – 2 5 mm) In two of these, this finding was overlooked primarily because of wrong measurement In the third case, the surgeon found no indication for operation in spite of the radiological finding (Table 1)

Sixty-two patients were transferred to the outpatient department After repeated clinical examination and, in some cases, repeated radiological examination (which is not included in the report), 42 of these patients were treated for ligament rupture with a plaster cast for 6 weeks Twenty were regarded as having a simple sprain (Table 2)

Table 1 The radiological diagnosis in 96 patients with simple sprain

Talar tilt investigation

Radiological diagnosis	Normal	Ligament lesion	Total
Normal	93	0	93
Ligament lesion	3	0	3
Total	96	0	96

One patient with a falsely positive TT finding was checked radiologically The first examination had revealed a distance between the articular surfaces of 6 mm on the injured side and of 3 mm on the unaffected side In the repeat exposure, the corresponding figures were 6 and 5 mm, respectively

Eighty-six patients were subjected to operation because of suspected ligament rupture At operation, ligament rupture was found in 85 of these patients, while the ligaments were intact in one (displacement difference 3 mm by ADS) In two cases, only a capsular lesion was found (in Table 3 these are recorded as a lesion of the anterior talofibular ligament) In three cases, both investigations were negative Of these patients two were operated on because of severe clinical symptoms of ligament rupture In both cases, a rupture of the anterior talofibular ligament was found The third patient was subjected to operation because of a primarily erroneous measurement, in this case a capsular lesion was found (Table 3)

During the period from Oct 1 to Nov 30 1976, the TT and ADS examinations showed almost the same efficiency During the subsequent period (Dec 1, 1976 – Feb 15 1977) a marked decrease in the efficiency of ADS was observed (Table 4)

DISCUSSION

In both investigations the purpose is the same, to disclose a ligament rupture by demonstration of instability of the talus either instability in the frontal plane (TT) or in the sagittal plane (ADS) It is well known that the degree of TT present in the normal ankle is highly variable (Rubin & Witten 1960) This was confirmed in the present series. Moreover, a great variability in the degree of ADS was found Because of the variation in normal ankles it is recommended that the instability of the injured ankle is compared with the movement of the normal ankle (Cedell 1975, Rubin & Witten 1960) This was also practised in the present study

Table 2 The clinical diagnosis in relation to the radiological diagnosis in 62 outpatients with suspected lateral ligament lesion of the ankle

Talar tilt investigation

Radiological diagnosis		Normal		Ligament lesion		Total	
	Clinical diagnosis	SS	LL	SS	LL	SS	LL
Normal	SS	14		3		17	
	LL		8		6		14
Ligament lesion	SS	3				3	
	LL		19		9		28
Total	SS	17		3		20	
	LL		27		15		42

SS simple sprain
LL ligament lesion

Table 3 The operative diagnosis related to the radiological diagnosis in 86 patients operated on because of suspected lesion of the lateral ligaments of the ankle (In one patient with positive ADS no lesion was found at operation)

Talar tilt investigation

Radiological diagnosis		Normal		Ligament lesion		Total	
	Operative diagnosis	LTF	LTF + LCF	LTF	LTF + LCF	LTF	LTF + LCF
Normal	LTF	3		4		7	
	LTF + LCF				15		15
Ligament lesion	LTF	10		3		13	
	LTF + LCF		12		38		50
Total	LTF	13		7		20	
	LTF + LCF		12		53		65

LTF lesion of the anterior talofibular ligament
LCF lesion of the calcaneofibular ligament

Table 4 Monthly distribution of the results of the talar tilt (TT) and the anterior drawer sign (ADS) examinations in 86 patients operated on because of suspected lesion of the lateral ligaments of the ankle

	Ligament lesion disclosed by			Positive investigation		Falsely positive investigation		ADS + TT negative	Total
	TT	ADS	Both	TT	ADS	TT	ADS		
October	2	3	11	13	14				16
November	5	8	11	16	19			1	25
December	2	7	9	11	16				18
January	4	3	7	11	10				14
February	6	1	3	9	4		1	2	13
Total	19	22	41	60	63		1	3	86

both in the TT and the ADS examinations A source of error in this comparison is a previous severe trauma on the now unaffected side None of the patients in the present series had been exposed to such a trauma

Ligament rupture was diagnosed if the TT on the injured side exceeded that on the normal side by 3 mm or more This limit corresponds to a difference of 6° as recommended by Freeman (1965)

Various methods have been recommended for measurement of the anterior instability by ADS (Castaing & Delplace 1972, Lindstrand & Mortensson 1976, Larsen 1976) In the present series ligament rupture was diagnosed by ADS if there was a difference in displacement of 2 mm or more between the two sides. The limit of 2 mm had been determined in a pilot investigation performed on patients with surgically verified ligament lesion

The fixed points chosen give the methods a great advantage over those used by other authors Both points represent midline structures, which means that both ankles can be examined from the same side Another advantage of the method presented is that the double exposure of the film makes it possible to measure the displacement on each side on the one film.

The figures quoted regarding the outdepartment group should be taken with a certain reservation, because of the absence of verification of the ligament ruptures However, if the clinical diagnoses are accepted as correct about 50 per cent of the ligament ruptures were disclosed only by the ADS This figure is very high, compared with the 25 per cent in this group with ruptures which were diagnosed only by the TT The explanation for this is probably a certain scepticism on the part of the clinicians as to the value of the ADS, so that patients with positive signs of ligament rupture disclosed only by the ADS were more often sent to the outpatient department than patients with positive signs of ligament rupture only by the TT

One or other of the methods failed in about 25 per cent of the surgically verified cases but the methods were complementary so that if one was negative the other was usually positive In only 5 per cent of the surgically verified cases were both methods negative at the same time In addition both methods were negative in 20 per cent of the ligament lesions in the outpatient department group The number of falsely negative examinations may possibly be reduced in both investigations by using local anaesthesia of the injured ligaments to avoid a pain-determined fixation of the ankle (Lindstrand & Mortensson 1976) Moreover it is possible that an increased load can reduce the number of falsely negative results with the ADS.

In the first period during which both methods were performed with meticulous care by one investigator, the efficiency of both methods was the same In the second period during which both the TT and the ADS examinations were used routinely the ADS being performed by X-ray technicians the efficiency of the ADS showed a definite decline The reason for this most probably is that it is of crucial importance that the patient is completely relaxed when the ADS examination is performed This requires some time, which may be difficult for the technicians to accept, especially in a stressed situation To make the ADS investigation just as efficient as the TT it is recommended that the examination be performed by doctors Otherwise very careful instruction of the technicians with constant checks giving special emphasis to the importance of a completely relaxed patient is necessary

The interpretation of the X-ray films was a little more difficult in the ADS investigation than in the TT However, with some experience this gave no special problems and in the reappraisal of all the exposures only a few false measurements were disclosed.

The ADS has some very great advantages over the TT Firstly, the ADS is definitely less painful for the patient and secondly the ADS is safer with regard to scattered radiation, because no member of the staff has to stay in the examination room during the exposure.

The anterior talofibular ligament is the most important stabilizing ligament of the ankle (Cedell 1975) Moreover, the anterior talofibular ligament is damaged in nearly 90 per cent of all ligament injuries in the ankle – in 66 5 per cent alone and in 20 per cent in combi[illegible] (Brost[illegible] import[illegible] ligament

In an experimental study, Castaing & Delplace (1972) found that cutting of the anterior talofibular ligament was followed only by anterior instability of the ankle joint (ADS). TT occurred only when the calcaneofibular ligament was also cut. By the two methods, it should therefore be possible to differentiate between lesions of the anterior talofibular ligament and combined lesions of the anterior talofibular and the calcaneofibular ligaments.

In the series presented here, isolated lesion of the anterior talofibular ligament was found in 25 per cent of the operated cases. When only ADS was positive, the lesion was more often localized to the anterior talofibular ligament. Localized lesion of the anterior talofibular ligament was, however, in some cases disclosed only by TT, and lesion of the calcaneofibular ligament was found in some cases in spite of the negative TT

Conclusions

Ligament lesions which are not disclosed by the TT examination may be diagnosed by the ADS

The ADS cannot replace the TT examination, or *vice versa* The two methods are complementary

It is not possible to differentiate between isolated lesion of the anterior talofibular ligament and a combined lesion of the anterior talofibular and the calcaneofibular ligament by the two methods

REFERENCES

[illegible] (1965)

Brostrom, L. (1966) Sprained ankles. Diss. Stockholm

Castaing J & Delplace J (1972) Entorses de la cheville. Intéret de l etude de la stabilité dans le plan sagital pour le diagnostic de gravité *Rev Chir orthop* 58, 51–63

Cedell, C-A. (1975) Ankle lesions. *Acta orthop scand* 46, 425–445

Freeman M. A. R. (1965) Instability of the foot after injuries to the lateral ligament of the ankle *J Bone Jt Surg* 47 B 669–677

Fulp M J (1973) Arthrography of the ankle *J Amer Podiatry Ass* 63, 502–511

Larsen, E (1976) Den instabile ankel. *Ugeskr Laeg* 138, 1989–1993

Lindstrand A. & Mortensson, W (1976) A roentgenological investigation of anterior instability in the ankle joint after acute lateral sprain. Lateral lesions in sprained ankles. A [illegible]

Rul[illegible] *Surg* 42 A 311–320

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LATERAL INSTABILITY OF THE ANKLE TREATED BY A MODIFIED EVANS PROCEDURE

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A technically simple tenodesis of the peroneus brevis tendon has b[illegible] applied in the treatment of 42 patients with lateral instability of the ank[illegible] 33 patients have been examined 2–10 years after the operation and 91 [illegible] cent showed excellent or good results It is concluded that this proced[illegible] gives good stability in the varus as well as the antero-posterior direct[illegible] and is therefore comparable to the technically more difficult Watson-Jo[illegible] procedure

Key words lateral instability of the ankle, tenodesis, peroneus bre[illegible] tendon

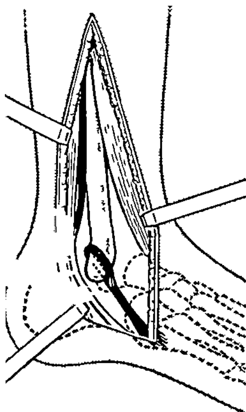
Accepted 21 i 78

Posttraumatic lateral instability of the ankle is a condition with well-defined clinical symptoms An inversion trauma sometimes leads to recurrent sprains, a feeling of instability, and periodic pain and swelling below and in front of the lateral malleolus. Several operative procedures to stabilize the ankle have been presented during the last 40 years In many of these the peroneus brevis tendon has been used as a substitute for the ruptured lateral ligaments. Brostrom (1966) considered a direct suture of the torn ligaments possible several years after the primary trauma In many cases however some kind of ligamentous reconstruction is necessary. Hitherto the Watson-Jones repair appears to be the most widely used procedure (Watson-Jones 1952, Anderson & Le Cocq 1954, Lemberger & Kramer 1971, Gillespie & Boucher 1971)

PATIENTS AND METHODS

Between 1964 and 1974, 42 patients with lateral [illegible] stability of the ankle were operated on in [illegible] orthopaedic department of Borås Central Hosp[illegible] The operative procedure used was a s[illegible] modification of those described by Nilsonne (19[illegible] and Evans (1953) A slightly curved incision [illegible] made over the peroneal tendons down to the tip [illegible] the lateral malleolus. The tendons are isolated [illegible] the level of the proximal retinaculum, which [illegible] be carefully preserved The peroneus brevis [illegible] is sectioned just below the musculo-tendin[illegible] junction. The proximal end is sutured to th[illegible] peroneus longus, while the distal end is dra[illegible] down through the proximal retinaculum. A chan[illegible] of about 7 mm diameter is then drilled in the late[illegible] malleolus from the tip directed proximally [illegible] dorsally The tendon is driven through the chan[illegible] [illegible] the periosteum (Fig[illegible] [illegible]

[illegible] in a below-knee walking cast for [illegible] wee[illegible] by mobilization with full weight-bearing



ure 1 Schematic illustration of the operation r suturing of the peroneus brevis tendon

ll the case records were almost identical A ıary heavy sprain was followed by a feeling of ability, weakness of the ankle, periodic pain recurrent sprains. The condition was in all s associated with marked physical disability in tion to sporting activities such as tennis, minton, golf and cross-country running ause of the large normal variations in talar tilt urin et al 1968) the operative indication was d more on the clinical status than on the X- examination.

ur series consisted of 21 male and 12 female ents. At the time the investigation was carried one of the 42 patients had died and eight rs were not available for other reasons (mainly use of the great turnover of inhabitants in this . of the country). The age at operation 33 years (range 15–63 years). The time primary trauma and operation averaged 6 (range 1–27 years) and follow-up time 5 rs (range 2–10 years).

t follow-up the patients outlined their sub- ve condition by answering a special questionnaire All the patients were examined clinically with respect to 1) Ankle joint mobility 2) Stability (varus instability and/or "drawer" symptom) 3) Peroneal function and circumference of the calf 4) X-ray (AP sagittal and forced supination).

RESULTS

No operative complications were recorded Table 1 presents the subjective results. In the group "improved" there were slight complaints such as swelling at the lateral malleolus (11 cases), sporadic distorsions (6 cases) and periodical pain (5 cases)

The three patients in the group "not improved" considered their ankle joints to be just as unstable as before operation One of these demonstrated a completely normal status clinically and on X-ray The ability to perform sports activities is presented in Table 2 Preoperatively no patient was able to take part in any form of sporting activity

Table 1 Subjective results in 33 operated cases

Result	No of cases	Per cent
No complaints	19	58
Improved	11	33
Not improved	3	9
Total	33	100

Table 2 Postoperative physical ability

Sporting activity	No. of patients	Per cent
Competitive athlete	6	18
Occasional sport	23	70
No sport at all	4	12
Total	33	100

At the clinical examination supination was reduced by less than 10° in 10 patients In five cases a very slight "anterior drawer sign" could be demonstrated, while no patients revealed varus instability Moderate swelling at the lateral malleolus was found in five cases Peroneal strength compared to the non-operated side was normal, and there was no atrophy of the calf muscles

Slight to moderate osteoarthritis was recorded in two patients and advanced osteoarthritis in one In two of these three cases, however, the X-ray picture was completely unchanged in comparison with the pictures taken preoperatively

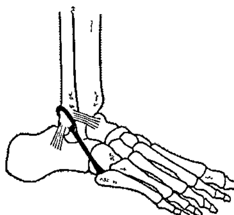


Figure 2 Position of the transplant between th two relevant ligaments

DISCUSSION

Lateral instability of the ankle is a disabling condition, which reduces the mobility of the patient, especially on uneven ground In elderly patients relief of symptoms may be obtained by nonoperative measures, such as peroneal strengthening exercises The majority of younger and middle-aged patients demand surgical treatment, in order to improve their physical performance In addition to the technique of direct suturing (Brostrom 1966) good results have been presented after use of the Watson-Jones repair (Watson-Jones 1952, Anderson & Le Cocq 1954, Lemberger & Kramer 1971, Gillespie & Boucher 1971) This repair includes a transfer of the peroneus brevis tendon through the talus, which makes the operation technically more difficult than the modified Evans procedure we have used The anterior fibulo-talar ligament is considered to be the most important of the lateral ligaments, from the point of view of stability (Leonard 1949, Brostrom 1966, Laurin et al 1968) The position of the transplant in the modified Evans procedure described here seems to substitute for the function of this ligament as well as that of the fibulo-calcanear ligament (Figure 2) The procedure was performed after sectioning of the two ligaments in a cadaveric specimen and a good stabilizing effect in the antero-posterior well as varus direction was noted. Th modified Evans procedure is a simple metho of treating lateral instability of the ankle. Th stabilizing effect seems very good. Also th subjective results are very gratifying

REFERENCES

Anderson, J K. & Le Cocq J F (1954) Operati treatment of injury to the fibular collate ligament of the ankle *J Bone Jt Surg* 36- 825–832

Brostrom L (1966) Sprained ankles. VI Surgic treatment of "chronic" ligament ruptures. *Ac chir scand* **132**, 551–565

Evans, D L (1953) Recurrent instability of th ankle – A method of surgical treatment *Pro roy Soc. Med* **46**, 343

Gillespie, H S & Boucher, P (1971) Wa Jones repair of lateral instability of the ankl *J Bone Jt Surg* **53-A**, 920–924

Laurin, C A, Quellet, R & St Jacques, R (19 Talar and subtalar tilt An experimental in vestigation *Canad J Surg* **11** 270–279

Lemberger, U & Kramer J (1971) Das instab obere Sprunggelenk *Helv chir Acta* 3 317–320

Leonard, M H (1949) Injuries of the later ligaments of the ankle *J Bone Jt Surg* 31 373–377

Nilsonne, H (1932) Making a new ligament ankle sprains *J Bone Jt Surg* 14 380–3

Watson Jones R (1940) *Fractures and joint injuries* E and S Livingstone Ltd, Edinburgh.

Watson-Jones R (1952) Recurrent forward dislocation of the ankle joint *J Bone Jt Surg* 34-B, 519

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CENTRIPETAL COMPRESSION TRIPLE ARTHRODESIS

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Forty-nine compression triple arthrodeses were performed in 45 patie

cases, and within 8 weeks in the remaining 63 per cent Non-union w completely avoided and the period until fusion reduced to almost half th expected after conventional operations. The compression also ensu maintenance of the correction of deformity initially obtained.

Key words foot, arthrodesis, triple arthrodesis by centripetal compress

Accepted 29 i 78

Since Ryerson described triple arthrodesis of the foot in 1923 the methods used for internal fixation of the tarsal bones have been either transfixation by Kirschner wires (Caldwell 1949) or staples (Burns 1946) The present paper presents a modified external compression technique which ensures a more rigid fixation of the tarsal joints. The use of compression shortens the healing time and prevents the occurrence of non-union

PATIENTS AND METHODS

Forty nine operations were performed in 45 patients (Table 1), 21 on the right side, 20 on the left and 4 bilaterally

The age of the patients ranged from 12 to 35 years with an average of 15 6 years. Thirty-eight patients were males, seven were females.

All patients were followed up clinically and roentgenologically for 1–6 years after the operation (average 4 years)

The fixation device is illustrated in Figures 1–3 It consists of

(1) Three Steinmann pins

(2) Two large rings each with three blocks w three transfixion screws in the end

(3) Six small transfixion rings

Table 1 Indications for centripetal compres triple arthrodesis

	Number of patients
Spasmodic flat foot	23*
Rigid painful static flat foot	3
Fractures of the calcaneus with involvement of the subtalar and calcaneocuboid joints	4
Poliomyelitis with deformed unstable feet	12
Pes cavus associated with spina bifida occulta	1
Neglected congenital talipes equinovarus	1
Chronic tarsal tuberculosis	1
Total	

* Four of these patients had bilateral

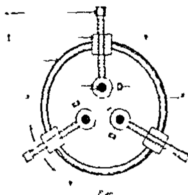


Figure 1 Diagram of the compression apparatus The movable block (1) The compression screw (2) whose smooth tip fits into a small hole in the small transfixion ring (4), which is anchored to the Steinmann pin (5) using a small screw (6) The large ring (3)



Figure 2 Postoperative X-ray showing the centripetal compression device applied to the foot

Each of the two large rings, 11 cm in diameter, has three movable blocks. Each block measures 3 x 2 x 2 cm with a central core 8 mm in diameter This permits free mobility around the ring and its axis. The block may be fixed at any desired point on the ring and in any desired plane by means of a screw Passing centrally through each block is a compression screw 45 mm in length. To the end of this screw a small transfixion ring is attached Through the transfixion ring the Steinmann pin is passed into the tarsal bones. By rotating the compression screw in the block its tip exerts pressure on the pins thus producing a centripetal compression of the resection surfaces.

The operation is performed through a medial incision centred over the talonavicular joint and an appropriate wedge is excised according to the deformity present. Following this a lateral incision starting 1 inch below the lateral malleolus and ending over the base of the fifth metatarsal is made. The peroneal tendons are retracted and the extensor digitorum brevis dissected distally and medially Another wedge is excised from the calcaneocuboid joint This facilitates posterior displacement of the forefoot. The talocalcaneal joint is thereafter resected with removal of an appropriate wedge in order to correct any heel deformity The first Steinmann pin is introduced laterally and downwards through the navicular and cuboid bones. The second is placed horizontally across the talar neck. The third pin is placed horizontally in the postero-inferior part of the os calcis.

The small transfixion rings are fixed to each end of the Steinmann pins a few centimetres away

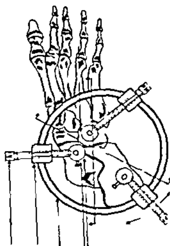


Figure 3 Diagram of the centripetal compression apparatus applied to the foot Note that one large ring is shown and that the three blocks can be moved to any part of the

CENTRIPETAL COMPRESSION TRIPLE ARTHRODESIS

M H El Ghawabi

Department of Orthopaedic Surgery Faculty of Medicine, Ain Shams University, Cairo Egypt

Forty-nine compression triple arthrodeses were performed in 45 |
whose av
applied to
two large
Union of
cases, and within 8 weeks in the remaining 6 3 per cent Non-uni
completely avoided and the period until fusion reduced to almost h
expected after conventional operations The compression also
maintenance of the correction of deformity initially obtained

Key words foot arthrodesis triple arthrodesis by centripetal com

Accepted 29 1 78

Since Ryerson described triple arthrodesis of the foot in 1923 the methods used for internal fixation of the tarsal bones have been either transfixation by Kirschner wires (Caldwell 1949) or staples (Burns 1946) The present paper presents a modified external compression technique which ensures a more rigid fixation of the tarsal joints. The use of compression shortens the healing time and prevents the occurrence of non-union.

PATIENTS AND METHODS

Forty nine operations were performed in 45 patients (Table 1) 21 on the right side, 20 on the left and 4 bilaterally

The age of the patients ranged from 12 to 35 years with an average of 15 6 years Thirty-eight patients were males, seven were females

All patients were followed up clinically and roentgenologically for 1–6 years after the operation (average 4 years)

The fixation device is illustrated in Figures 1–3 It consists of

(1) Three Steinmann pins
(2) Two large rings each with three bloc three transfixion screws in the end
(3) Six small transfixion rings

Table 1 Indications for centripetal com triple arthrodesis

	Num pat
Spasmodic flat foot	
Rigid painful static flat foot	
Fractures of the calcaneus with involvement of the subtalar and calcaneocuboid joints	
Poliomyelitis with deformed unstable feet	1
Pes cavus associated with spina bifida occulta	
Neglected congenital talipes equinovarus	
Chronic tarsal tuberculosis	-
Total	4

* Four of these patients had bilateral ope

Charnley, J & Baker, S L (1952) Compression arthrodesis of the knee A clinical and histological study *J Bone Jt Surg* 34-B, 187–199
R. L., Hathaway, E N & Parrish, F F (1950) Operations on the foot A study of the indications, technics used and results. *J Bone Jt Surg* 32 A, 1–26
Ryerson, E W (1923) Arthrodesing operations on the feet *J Bone Jt Surg* 5, 453–471
Wilson, F C, Fay, G F, Lamotte, P & Williams, J C. (1956) Triple arthrodesis. A study of the factors affecting fusion after three hundred and one procedures. *J Bone Jt Surg* 47-A, 340–348

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CALCANEAL CYSTS

A Radiological and Anatomico-Pathological Study

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University of Geneva, Switzerland

A radiological and anatomico-pathological study of 17 cases of calcane[illegible] ... documented ...

hemorrhages, (2) newly formed bone – similar to that observed in some cysts of the humerus and femur – applied to preexisting trabeculae wh[illegible] forms a bony wall explaining the typical radiological picture

These uncommon cysts may be the evolution of purely local hemorrhage in the trigonum calcis

Key words: bone cysts, calcaneum, intra-osseous hemorrhage, cholester[illegible] granuloma

Accepted 1.xi.77

Calcaneal cysts are quite uncommon and since Smith's observation (1930) only about 100 cases have been reported in the literature Most of these were asymptomatic

Seventeen surgically removed calcaneal cysts were studied and this report deals with their radiological and pathological appearances

MATERIAL AND METHODS

Each of the 17 subjects (15 men and 2 women) with ages ranging between 10 and 37 years (average 23 years, s.d. 5 35) had a unilateral cyst of the anterior calcaneus. Five were situated on the right and seven on the left In five cases the side was not mentioned.

Four patients complained of moderate heel pain. In the remaining cases the cyst was an accidental radiological finding (often after a minor trauma) A surgical curettage was performed in all cases.

The material, fixed in 10 per cent formalin, [illegible] paraffin embedded, and sections were stained [illegible] hematoxylin-eosin (HE) van Gieson, Gomor[illegible] silver impregnation and Pearl's stain. In one c[illegible] lipids were looked for with the Oil red O stai[illegible] gelatin embedded tissue

OBSERVATIONS

Radiology

The radiological picture in each case was the [illegible] of an anterior calcaneal lacuna with an almos[illegible] trapezoidal form, sometimes circumscribed by [illegible] thin border of condensed bone (Figure 1). On tw[illegible] occasions, axial views revealed a lateral posi[illegible]

Pathology

Histologically, the material was made up es[illegible] sentially of a wall of fibrous scar tissue (Figure [illegible] containing varying quantities of hemosider[illegible] (Figure 3a) In seven cases cholesterol was note[illegible] (directly with Oil red O or indirectly with HE or [illegible] van Gieson) within histiocytes or in the form of [illegible] crystals provoking a foreign body giant cell reactio[illegible]

* Aspirant du Fonds National de la Recherche Scientifique Belge.





igure 1 X ray of anterior calcaneal cyst (lateral iew – 0 9×) (a) Cyst surrounded by a well lefined bony border (T 12634/67 — 22 year old nale) (b) Cyst with a 'leafy' wall (T 5093/66 — 7 year old male)





Figure 2 Histological appearance of the cyst wall (T 4081/76 – HE stain – 6×) Lower right compact lamellated bone To the left mostly lamellated remodelled bone (and in places woven bone) Superior border of this bony wall is covered by a layer of connective tissue which lines the cyst cavity (a) Normal light (b) Polarized light

F gure 3b). In three cases the fibrous material intermingled with newly formed coarse ibrillar osteoid tissue This was either typically 'reparative" (Figure 4) or composed of flakes with peculiar woven appearance (Figure 5) In two of cases the fibrous osteoid tissue was to partially remodelled preexisting (Figures 2 and 4) The 14 remaining non specific osteogenic and fibrous which could be due to variations in the the excised material

Infectious or tumoral lesions as well as bone in were excluded on histological examina

..

Our findings were compared to those described in the literature and from these comparisons a number of interesting points have arisen

The average age in both series is comparable [20 years in the literature but with a greater variation ranging from 4 years (Kingsbery 1957) to 65 years (Denis 1965)] There is definitely a male predominance which was also present in our series. The cysts may be seen on either side with about equal frequency but bilateral cysts are rarely observed (Bachiocco & Leonessa 1968 Christman & Kopell 1961 Kingsbery 1957 Lentini 1967)

A history of trauma is found in approximately one out of ten cases. Only two reports from the literature mentioned the presence of fractured cysts (Aegerter & Kirkpatrick 1968 Malcapi & Turrini 1963)



Figure 3 Detail of connec tissue portion of cyst wall 12634/67) (a) Fibrous tissue clefts of cholesterol crystals half) near ad pose tissue contan hemosiderin deposits (lower Pearl's iron stain (no counte of the nuclei) – 36× (b) Gran tion tissue with clefts of cholest crystals and giant cells (right joined to fibrous tissue (left bor van Gieson 8×

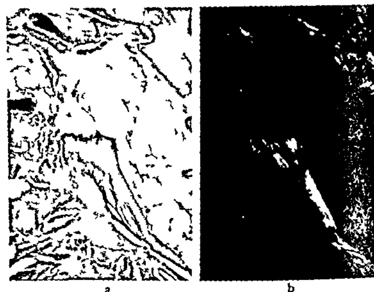


Figure 4 Deta l of connec tissue external area of cyst (T 12634/67 – HE – 13 5×) left granulation tissue with of cholesterol crystals center preexisting lamellated trabeculae Top newly fo woven bone (a) Normal l Polarized light

Pain is only present in one fourth of the cases and thus correlates well with our series Frequently the pain is accentuated by pressure and especially when walking Swelling which has been noted by various authors was not noted in the present series Radiologically one case was considered as having healed spontaneously 21 years after diagnosis (Smith & Smith 1974)

In the literature there are about 40 histologically proven cases described including one in a specimen from an amputated limb (Calcagni 1963) All of these cases showed fibrosis frequently accompanied by hemosiderin deposits foam cells cholesterol crystals and a hemorrhagic fluid in the cavity (Aegerter & Kirk 1968 Ayres & Cameron 1957 Bachiocco Leonessa 1968 Palma & Venturini 1969)

Differential diagnosis

Evidence accumulated from the literature and from our own observations is sufficient for the recognition of an entity to be referred to as the "anterior calcaneal cyst" based on the characteristic radiological picture associated with the finding of cyst at surgery Osteogenic scar tissue hemosiderin as well as cholesterol deposits seem to be the main histological characteristics

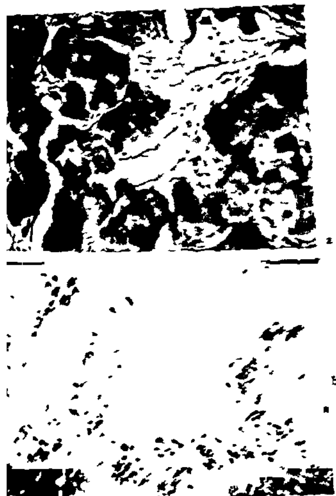


Figure 5. Osteoid flakes with special woven appearance. Dilat capillaries in the intertrabecul spaces (T 5272/74 – HE – 47×) (a) Normal light. (b) Polariz light.

These cysts should be differentiated from other calcaneal cysts and especially those in the posterior superior calcaneus which have been documented twice in the literature (Barbieri 1969, Christman & Kopell 1961). They should obviously be differentiated from erosive conditions of the calcaneus described in relation to xanthomatosis of the Achilles tendon (Sneider 1963).

Furthermore, they should not be confused with infectious and tumoral lesions which have different radiological appearances and can be found in any area of the calcaneus (Bonnet et al. 1968, Denis 1965). In fact, all infectious and tumoral (benign or malignant) lesions that may affect the skeleton have been observed in this bone.

A calcaneal cyst related to an arthropa, such as described in a case of rheumat arthritis (Copeman 1955) is exceptional a must be integrated into the over radiological findings. A radiological a anatomic study of a calcaneus, modified by old Sudeck's dystrophy, has shown that th does not resemble a case of calcaneal cy (Lagier & Van Linthoudt, in press).

It is also necessary to eliminate all of thos cases presenting similar radiological picture which do not have the anatomico-pathologica criteria of a cyst, such as bone lipomas (Appenzeller & Weitzner 1974, Poussa & Holmstrom 1976).







gure 6 Normal calcaneus (A 609/71 – 63 year ld male – right side – 0 7×) (a) X-ray of the lateral half (b) Macerated specimen corresponding to the preceding X-ray (c) Medial parasagittal section (embedded in celloidin – HE stain) Bone marrow consists mostly of fatty tissue particularly in the trigonum calcis



Figure 7 Arterial supply of normal calcaneus (T 1369/77 – 60 year old male – left side – x0.7). Lateral parasagittal section. Arterial blood vessels are injected with Indian ink. Transparency of bone obtained by the Spalteholz technique

Pathogenesis and characteristics

From our observations three main characteristics explaining the pathogenesis of these cysts can be formulated

(1) These cysts, because of on could be considered as a normal anatomical pattern It is the trabecular architecture of t forms at this level the u

delimited above by an arch of trabeculae whose structure is influenced by the stress of body weight and below by concave trabeculae situated against the corticalis which are affected by traction Photo-elastic studies on models (Milch 1940, cited in Lentini 1967) have shown that this zone remains free from the mechanical strains affecting the neighbouring areas. The interior of the trigonum contains fatty bone marrow, thus under normal conditions an anterior radiolucent area appears on the X-ray of a calcaneus and this may at times be accentuated, causing the pseudo-cystic images described by Sirry (1951) in 7 1 per cent of his series (Figure 6). These areas can be differentiated from true cysts by the fact that they are triangular in form and do not have a limiting bony wall.

(2) The histology showed that the bony wall of the cysts developed by an osteogenic metaplasia against the preexisting lamellar bone trabeculae and on the exterior surface of thin scarred connective tissue containing deposits of hemosiderin and cholesterol. It is well documented that this type of scarred connective tissue is due to the organization of hemorrhages such as that observed in the case of cholesterol granulomas of the ear or in experimental models (Dota et al. 19 1959, Main et al. 1970). consider these cysts of the to be the result of

organizing hemorrhages in the region of the trigonum calcis. This could be related to the rather rich vascularization of this area (Chanzy et al. 1973, Crock 1967) (Figure 7) It suggests a pathogenesis already proposed by Pommer for bone cysts, one which was also discussed for the formation of humeral and femoral cysts (Jaffé & Lichtens- te 1942, Lang 1954, Pommer 1919) In fact, have observed that the newly formed bone in the wall of humeral or femoral cysts – which also develop under an arch of trabeculae – may be represented by the same peculiar woven osteoid material seen in Figure 5 Their great rarity (even after trauma) and the lack of any relation with hemorrhagic conditions [the hemophiliac cysts of the calcaneus have a different appearance (Bonnet et al 1968, Giambelli & Lanzetta 1964)] implies that an exceptional combination of various mechanical and vascular factors must be necessary for their formation Among other things there may even be a *relationship* with the venous ... of the lower leg When this is increased, the pressure within the calcaneus also increases (Arnoldi & Linderholm 1971)

ACKNOWLEDGMENTS

We would like to express our gratitude to Prof B de Montmollin (Neuchâtel), Prof H. G Willert (Frankfurt-am-Main), Dr J Barambon (Geneva), Dr P Corboud (Fribourg), Dr M Duc (Sion), Dr R. Faller (Moutier), Dr E Jeannet (Lausanne), Dr A Megevand (Geneva) and Dr J-Ch. Mottironi (Geneva) for supplying us with the clinical and radiological findings of the cases that we studied

REFERENCES

Aegerter, E & Kirkpatrick, J A (1968) *Orthopaedic diseases* Vol. I, 3rd ed. Saunders Co Philadelphia

Appenzeller, J & Weitzner, S (1974) Intraosseous lipoma of os calcis. Case report and review of literature of intraosseous lipoma of extremities *Clin Orthop* 101, 171–175

Arnoldi, C C & Linderholm, H (1971) Intracalcaneal pressure in various forms of dysfunction of the venous pump of the calf *Acta chir scand* 137, 21–27

Ayres, W W & Cameron, B M (1957) Cysts of the os calcis. *U S armed Forces med J* 8, 1102–1117

Bachiocco, R & Leonessa, C. (1968) Su tre casi di cisti ossea bilaterale simmetrica del calcagno *Chir Organi Mov* 57, 427–433

Barbieri, L. (1969) Su due rare affezioni del calcagno le cistis ossee e la malattia di Paget *Minerva ortop* 20, 328–332.

Bonnet, J, Garreta, L. & Ducloux, J-M (1968) Les lacunes calcanéennes. *Ann Radiol.* 11, 171–184

Calcagni, V (1963) Sulla cisti ossea solitaria giovanile del calcagno. *Minerva ortop* 14, 556–560

Christman, R O & Kopell, H P (1961) Bilateral benign bone cyst of the os calcis. *Amer J Roentgenol.* 86, 318–320

Chanzy, M., Duclos, J-M & Alexandre, J-H (1973) La vascularisation veineuse du calcaneum *Arch Anat path.* 21, 311–316.

Copeman, W S C (1955) *Textbook of rheumatic diseases* Vol. I, 2nd ed E & S Livingstone Ltd., Edinburgh and London

Crock, H (1967) *The blood supply of the lower limb bones in man.* Vol 1, 1st ed, E. & S Livingstone Ltd, Edinburgh and London

Denis, A (1965) Quelques aspects de la pathologie tumorale du calcanéum. Observations de kyste solitaire du calcanéum, de kyste anévrysmal, de réticulo-sarcome du calcanéum *Rev Rhum* 32, 762–768

... Sasaki Y ... *Otol (St* ... olesteatoma and cholesterol granuloma. *Ann. Otol. (St Louis)* 68, 57–79

Giambelli, G & Lanzetta, A. (1964) Affections rares du calcanéum *Presse méd* 72, 3001–3004

Jaffé, H L. & Lichtenstein, L. (1942) Solitary unicameral bone cyst. With emphasis on the roentgen picture, the pathologic appearance and the pathogenesis. *Arch Surg* 44, 1004–1025

Kingsbery, L. B (1957) Solitary cyst of the os calcis in adults and children. Report of 8 cases. *J int Coll. Surg* 27, 83–91

Lagier, R. & Van Linthoudt, D Confrontation anatomo-radiologique sur la dystrophie de Sudeck de l arrièrepied. *Ann. Radiol* (in press).

Lang, F J (1954) Le cisti "genuine" delle ossa [illegible]

[illegible]

Organi Mov 56, 36–56

Main, Th. S , Shimada, T & Lim, D J (1970) Experimental cholesterol granuloma *Arch Otolaryng* 91, 356–359

Malcapi, C & Turrini, P G (1963) Cisti ossea solitaria del calcagno *Minerva ortop* 14, 445–451

Milch, H (1940) Photo-elastic studies of bone forms. *J Bone Jt Surg* 22, 621–626.

Palma, V & Venturini, G (1969) Su di un caso di cisti ossea solitaria giovanile del calcagno *Minerva ortop* 10, 533–538

Pommer, G (1919) Zur Kenntnis der progressiven hämatom- und Phlegmasie-veränderungen der Rohrenknochen auf Grund der mi skopischen Befunde im neuen Kno enzystenfalle H v Haberes. *Arch. orl Unfall Chir* 17, 17–69

Poussa, M. & Holmstrom, T (1976) Intraos lipoma of the calcaneus. Report of a case an short review of the literature. *Acta orth scand* 47, 570–574

Sirry, A (1951) The pseudo-cystic triangle in normal os calcis. *Acta radiol. (Stockh.)* 516–520

Smith, N R. (1930) Cyst of the os calcis. *J B Jt Surg* 12, 416

Smith, R. W & Smith, C. F (1974) Solitary cameral bone cyst of the calcaneus. A rev of twenty cases. *J Bone Jt Surg* 56 49–56

Sneider, P (1963) Xanthoma of the calca *Brit J Radiol.* 36, 222–223

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DEGENERATIVE CHANGES IN THE FIRST METATARSO-PHALANGEAL JOINT OF BALLET DANCERS

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In 20 female performers of classical ballet the range of dorsiflexion of the big toe was found to be significantly decreased However, in only one case was the decrease sufficiently great to interfere with the dancer's ability to perform. In spite of the severe stress put on the first metatarso-phalangeal joint in dancers the resulting degenerative changes were found to be minor and in most instances without clinical consequences. The results indicate that professional ballet, contrary to what is generally believed rarely has harmful effects on the first metatarso-phalangeal joint.

Key words ballet, dancing, hallux rigidus

Accepted 24 i 78

Degenerative changes, mostly osteophytes, particularly in the talar joint have been demonstrated in female performers of classical ballet (Brodelius 1961, Miller et al 1974) Dunn (1965) pointed out the importance of protection of the big toe and the metatarso-phalangeal joints in dancers, particularly female dancers who dance with their feet in the "sur la pointe" position. Dancing with a rigid first metatarso-phalangeal joint puts considerable strain on the foot and ankle and tends to create a "sickling" position with supination of the foot which in turn causes pain and spoils the dancing posture Similar observations have been presented by Miller et al. (1974) indicating that hallux valgus, bunions and callosities are common in the feet of female dancers. So far, no reliable method has been devised to protect the first metatarso-phalangeal joint in female dancers, nor has any series of successful surgical procedures for hallux rigidus in female performers of classical ballet been presented

The objective of this study was to measure the range of motion in the first metatarso-phalangeal joints in female ballet dancers and to make a comparison with a control population of non-dancers.

Financial support was obtained from the Swedish Medical Research Council (project No B 77-17X-2737-09B), Greta and Johan Kock's Foundation and Alfred Österlund's Foundation.

MATERIAL AND METHOD

Included in the study were 20 female ballet dancers, members of the ballet company of the Malmo City Theatre, and 34 approximately age-matched controls, mainly hospital employees without any history of injury or disease of the forefoot. The age of the dancers was 28 ± 7 They were all professional and had been dancing since early childhood. The range of motion was tested in the same way and by the same investigator in all the subjects using a square rule (Figure 1). In the ballet dancers additional measurements were

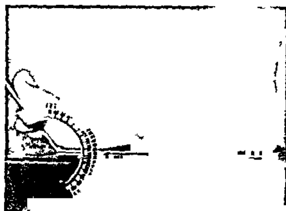


Figure 1 Measurement of dorsiflexion of the first metatarso-phalangeal joint The maximum dorsiflexion is measured with the patient standing and the ankle joint in the neutral position.

taken immediately after a performance The average of left and right was used since there was no systematic left-right difference

RESULTS

There was no significant change in the range of motion with age either in the dancers or in the controls (Figure 2) There was, however, a difference in the range of motion between the two groups which only amounted to a few degrees, this difference was significant ($0.02 > P > 0.01$) In fact, only one dancer H, aged 23) deviated significantly from rest of the cases and this girl also had clinical symptoms associated with her dancing There was no difference in the range of motion in ballet dancers before and immediately after a performance Radiograms were obtained of the six female dancers who had the most restricted range of motion. Of these six, three were found to have small osteophytes on the margins of the metatarsal head, however, the radiological signs were not associated with clinical symptoms except in the one girl mentioned above with a range of motion decreased by about 40 per cent.

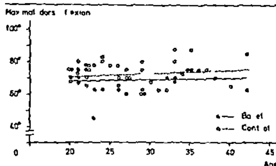


Figure 2 The relationship of age and big toe dorsiflexion in female dancers and age-matched controls



Figure 3 The foot of dancer (K H) in sur le pointe" position Note the perfect arch of foot and toes which supports the entire body weight.

DISCUSSION

There is little doubt that in female ballet dancers a tremendous load is taken by the first metatarso-phalangeal joint in the "pointe" position and that this joint is

subjected to repeated trauma over the years (Figure 3) Also, the appearance of the feet of these performers with large multiple callosities supports the concept that the toes and particularly the big toe are weight- structures Under these conditions it surprising that so few and so moderate changes were found It should be noted that the radiological changes mentioned above were only osteophytes and not osteoarthritis in its true sense In conclusion, ballet dancing may not be as harmful to the forefoot of young women as has been proposed in the past

REFERENCES

Brodelius, Å (1961) Osteoarthritis of the talar joints in footballers and ballet dancers *Acta orthop scand* 30, 309–314

Dunn, B (1965) Physiotherapy and the ballet *Physiotherapy* 51, 125–128

Miller, E H, Schneider, H J, Bronson J L & McLane, D (1974) A new consideration in athletes injuries. *Clin Orthop* **111**, 181–191

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ANNOUNCEMENT

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SIMULTANEOUS TRAUMATIC POSTERIOR DISLOCATION OF BOTH HIPS

A Case Report

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Simultaneous traumatic posterior dislocation of both hips, uncomplicated by fracture, is an exceptionally rare entity The authors could not find any record of a similar case in the world medical literature up till now, and are therefore reporting this case with special consideration of the mechanism of injury and the management.

Key words dislocation of hips, bilateral posterior

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CASE REPORT

A 56-year-old male of thin build was travelling seated in the rear seat of a car He was rather tightly placed between other passengers. When the car had a head-on collision with another vehicle he was pushed forward with great force jamming his knees against the back of the front seat Following the incident the patient was brought to the Nemazee Hospital with complaints of severe pain in both hips and inability to move the hips and straighten the legs He was found to be in shock with both inferior extremities in flexion adduction and internal rotation so that the legs were almost crossing each other All active and passive movements of both hips were absent. Both the femoral heads were palpable in the gluteal areas. There were no signs of other lesions.

X-rays demonstrated posterior dislocation of both hips (Figure 1) The hips were reduced under general anaesthesia with the patient lying supine on the floor X-rays confirmed that the reduction was successful. At the most recent follow-up 6 months after the injury he remained symptom-free with normal radiological findings.



Figure 1 X-ray showing posterior dislocation of both hips

DISCUSSION

Most posterior dislocations of the hips are due to dashboard injury to the flexed adducted leg of the front-seat passenger (Apley 1976) Our patient was unusual in that he was a rear-seat passenger He was seated with both legs flexed and adducted at the hips when a forceful impact of the knees against the back of the front seats led to simultaneous dislocation of both hips.

Bilateral dislocation of the hips associated with fractures of either femur or acetabulum has already been described by Lyddon &

Hartman (1971) and Ingram & Turner (1954), but an uncomplicated case such as this has not been recorded so far

REFERENCES

Apley, A G (1976) *A system of orthopaedic fractures* 4th ed Butterworth Ltd, London

Lyddon, D W, Jr & Hartman, J T (197-) Traumatic dislocation of hips with ipsilateral femoral fractures. A case report. *J Bone J S* -- 53 A 1012–1016

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EFFECT OF INDOMETHACIN ON COLLAGEN METABOLISM OF RAT FRACTURE CALLUS *IN VITRO*

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The collagen metabolism of callus tissue from closed non-immobilized rat femoral fractures was studied *in vitro* after *in vivo* treatment with indomethacin 2 mg/kg/day for 6, 9 and 12 days after fracture Total hydroxyproline synthesis and incorporation of hydroxyproline into collagen were found to be significantly increased after indomethacin treatment whereas no significant difference was found regarding collagen resorption. The results suggest that the recently demonstrated inhibition of fracture healing by indomethacin is not brought about by an inhibition of collagen synthesis.

Key words anti-inflammatory agents bone, callus, fractures, indomethacin, rats

Accepted 6 ii.78

Non-steroidal antiphlogistica are used for the treatment of a wide range of diseases. They are also used to reduce the acute inflammation following trauma Most publications studying the effect of these drugs on fracture healing conclude that such treatments do not affect the healing process (Eschberger 1973, Nordenram & Bang 1970)

However, three recent publications report delayed fracture healing in experimental models after indomethacin treatment (Huusko et al 1975, Sudmann 1975, Rø et al 1976) The effect of antiphlogistic drugs on collagen outside bone has been studied by many authors and results are divergent (Aalto & Kulonen 1972, Famaey et al. 1975, Fukuhara & Tsurufuji 1969, Kulonen & Potila 1975, Lee 1968, Lee & Tong 1970 Morton & Malone 1972, Winter 1965) The divergent results may depend on the different doses administered (Aalto & Kulonen 1972, Kulonen & Potila 1975)

The present study was planned to investigate the effect of indomethacin administered *in vivo* on the *in vitro* metabolism of collagen of fracture callus tissue from rats. In the system used both collagen synthesis and resorption can be studied separately (Flanagen & Nichols 1969, Langeland 1975)

MATERIAL AND METHODS

Forty-two male rats of the Wister/Møllegaard strain were divided into two matched groups. One group received indomethacin 0 4 mg (Indocid suspension 0 4 mg/ml, Merck Sharp & Dohme, Haarlem, The Netherlands) by stomach tube once daily The resultant dose of indomethacin was about 2 mg/kg/day The other group serving as a control was given equivalent amounts of the vehicle The first doses was given immediately after having fractured the animals' left femur (Rø et al. 1976)

The treatment was continued until sacrifice of the animal. The pair matched animals were divided into three series.

* Dr Rø died in April 1976.

I Twelve rats sacrificed 6 days after fracture and start of treatment Initial weight 194 9 ± 4 7 g At sacrifice the indomethacin treated animals weighed 222 8 ± 8 1 g and their controls 214 0 ± 14 4 g The difference was not significant
II Twelve rats sacrificed 9 days after fracture and start of treatment Initial weight 194 9 ± 4 7 g At sacrifice the indomethacin treated animals weighed 234 3 ± 7 7 g and their controls 234 3 ± 8 9 g The difference was not significant
III Eighteen rats sacrificed 12 days after fracture and start of treatment Initial weight 197 4 ± 2 8 g At sacrifice the indomethacin treated animals weighed 245 7 ± 8 5 g and their paired controls 251 1 ± 9 3 The difference was not significant

The animals of series I and II, treated for 6 and 9 days, were, at the end of the experiment, anaesthetized with ether Blood was collected from the vena cava for indomethacin analysis and after that the animal was bled to death

The animals of series III, treated for 12 days, were, at end of the experiment, killed by a blow to the neck and decapitation

In all animals the left hind limb with the fractured femur was exarticulated at the hip joint and immediately cooled to 0°–2°C While still in the cold (0°–2°C) the callus tissue was carefully dissected free

The 6- and 9-day-old callus was cut into 0 5 mm slices in a microtome while the 12-day-old callus was cut into pieces of 1–2 mm³ by hand (Flanagan & Nichols 1969) The subsequent procedure, including the incubation, was as previously described (Borle & Nichols 1960, Flanagan & Nichols 1969, Langeland 1975) To the media were added proline 1 5 mM and Proline (U)-^{14}C (SA 290 mCi/mmol, from the Radiochemical Centre A...

...osphere of 95 per cent O_2/5 per cent CO_2 in a New Brunswick Incubator G 24 (New Brunswick, New Jersey USA) at 100 oscillations/min and 37 5°C for 6 hours 4 ml of medium was added to each flask

The decanted medium was immediately chilled to 0°–2°C, then centrifuged at 5000 *g* for 10 minutes and hydrolyzed in equal amounts of 12 N HCL in sealed ampoules at 125°C for 4 hours.

The callus tissue was, immediately after incubation, chilled to 0°–2°C, washed in two changes of chilled Krebs-Ringer buffer and hydrolyzed in 6 N HCL (2 ml/100 g wet weight) in sealed ampoules at 125°C for 18 hours.

Analysis The tissue hydrolysates were treated with humin precipitate (Prockop & Udenfriend 1960), centrifuged and the volume was adjusted

The amount of hydroxyproline was deter[mined by] the direct acid method of Firschein (Fir[schein &] Shill 1966 Firschein 1969) To determ[ine the] specific activity of the hydroxyproline [an] amount of hydrolysate was evaporated [...] The residue was dissolved in 250 µl aq[...] and hydroxyproline was isolated using a [...] 50 W-x8 200–400 mesh, 0 8 × 20 cm col[umn as] described by Firschein (1969) The hydrox[yproline] fraction of the eluate was once again evap[orated,] dissolved and put on a TLC-plate (TLC [...] Woelm 20 × 20 cm, pre-coated silica [...] 254/366 ...

...produce a pink colour The portion of sil[ica] containing the hydroxyproline (3 mm stripe[...]) eluated in 2 ml H_2O and centrifuged f[or ...] minutes at 5000 *g* Of the eluate 150 nl was [used] for hydroxyproline analysis according to the [...] acid method of Firschein (Firschein & Shill [...]) while 1500 nl was added to 20 ml Unisol[...] (Koch Light) and counted in a Nuclear-Ch[icago] Mark II Liquid Scintillation counter Sp[ecific] activity was calculated based on these re[sults] Media from 1–3 hours and 4–6 hours [...] pooled, treated and analysed as previo[usly] described (Juva & Prockop 1966 Langeland 19[...]

Calculations were done as described by Flana[gan] & Nichols (1969) and the statistical significance [of] differences was tested by the Wilcoxon [...] (Wilcoxon 1947) or the Wilcoxon Van Eltern t[est] for grouped data (Høyland & Walløe 1975).

RESULTS

The wet weight of the callus tumour is given in Figure 1 At 6 days there was no difference between indomethacin treated and untreated animals in this respect However, comparing the grouped data of 6, 9 and 12 days the indomethacin treated animals had a higher weight of callus tumour than their controls The same tendency can be seen when studying the total collagen content of callus tumour (Table 1) although these differences are insignificant Both the total hydroxyproline synthesis (Figure 2) and the deposition of hydroxyproline into collagen of callus tissue (Figure 3) are significantly higher in the indomethacin treated animals. Studying the deposition of hydroxyproline into collagen this parameter is higher in the treated

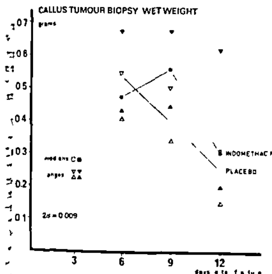


Figure 1 Wet weight of callus tumour Medians and ranges are given. The difference between the grouped data is significant (2α = 0 009)

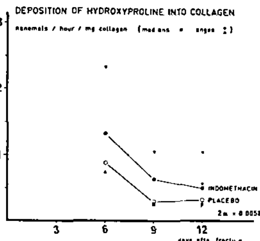


Figure 3 In vitro deposition of hydroxyproline into collagen of callus tumour The difference between the grouped data is significant (2α = 0 0058)

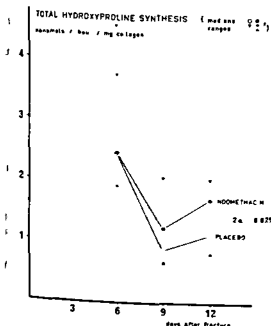


Figure 2 The total in vitro *synthesis of hydroxyproline in callus tumour The difference between grouped data is significant (2α = 0 029)*

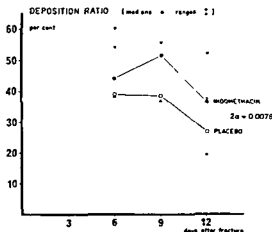


Figure 4 The ratio between synthesized collagen and collagen deposited in the callus tumour The difference is significant (2α = 0 0076)

animals throughout the experimental period, and so is the deposition ratio, i e , the ratio synthesis of collagen/deposition of collagen (Figure 4) (Flanagan & Nichols 1969)

The *in vitro* resorption of collagen is dealt with in Figure 5 For this parameter there were no significant differences between indomethacin and placebo treated animals.

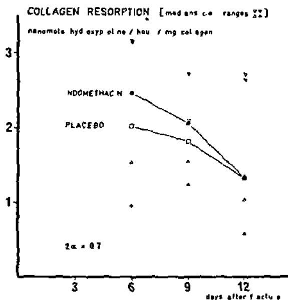


Figure 5 The in vitro *resorption of collagen (hydroxyproline) from incubated callus tissue There was no significant difference between indomethacin and placebo treated animals (2α 0 7)*

DISCUSSION

In a previous study from our laboratory (Rø et al 1976) an impaired mechanical strength of the same type of fractures in the same type of animals given the same amount of indomethacin was reported Tensile strength, elastic stiffness and maximal bending moment were all impaired in the indomethacin treated als While fracture union was observed ithin 18 to 24 days in the control animals, the fractures of the indomethacin treated animals were still unstable at the end of the experiment 24 days after fracture However, large cartilaginous collars around both fracture ends were found in these animals and a slit-like cavity was found between the en This slit was lined with fibrous tissue a fibrin on days 9 and 12. New bone format was delayed as compared to the cont animals

The present study deals with the in vi metabolism of the organic component of bo and callus, and it demonstrates clearly t the synthesis and deposition of collagen callus is higher in the indomethacin trea animals than in their controls. This is con tent with the findings of Alto & Kulon (1972) and Kulonen & Potila (1975) as fa low doses of indomethacin are concerned, is to be expected if the primary effect of domethacin is an inhibition of prostaglan synthesis (Vane 1971, Raisz & Koolema Beynen 1974) However, others have repo inhibited collagen synthesis after domethacin treatment (Winter 1965, Fukuh & Tsurufuji 1969) and this might be m easily explained in relation to the impa mechanical properties of the fractures.

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As regards the *in vitro* results of present study it may be argued that if ther a direct effect of indomethacin on bone c the drug may be washed away during p paration of the tissue for incubation. T the *in vitro* metabolism might take pl without the influence of indomethac However, from Figure 1 and Table 1 it be realized that callus tumour weight a

Table 1 Collagen content in callus tumour in mg Medians and ranges are given Differences are insignificant (2α=0 058)

Days after fracture	n	Placebo	n	Indomethacin
6	6	10 0 (6 9–13 3)	6	11 0 (6 9–21 0)
9	6	17 1 (13 8–18 9)	6	19 0 (13 9–20.2)
12	9	13 6 (8 2–16 0)	9	14 8 (8 8–20 5)

collagen content in callus tumour, both reflecting the *in vivo* metabolism, were higher in the indomethacin treated rats than in the controls Thus both the *in vitro* and *in vivo* experiments indicate that indomethacin treatment produces a higher rate of collagen synthesis in callus.

The present study suggests that the recently demonstrated impaired mechanical strength of rat femur fractures is not caused by an inhibition of collagen synthesis It seems that indomethacin treatment produces a collagen of lower quality and some observations might indicate that indomethacin may interfere with the transformation of immature connective tissue to calcified callus and bone This should be investigated further, as should the possibility the greater instability of the fractures of indomethacin treated animals may be responsible for the larger callus tumour and at least some of the increased collagen synthesis

REFERENCES

Aalto M. & Kulonen, E (1972) Effect of serotonin, indomethacin and other antirheumatic drugs on the synthesis of collagen and other proteins in granulation tissue slices. *Biochem. Pharmacol* **21**, 2835–2840

Borle A B & Nichols, G (1960) Metabolic studies on bone in vitro 1 Normal bone. *J biol. Chem.* **235**, 1206–1210

Eschberger, J (1973) Die Beeinflussung der Knochenbruchheilung durch Oxyphenbutazon. *Wien med Wschr* **123**, 315–319

Famaey, J-P., Brooks, P M & Dick, W C. (1975) Biological effects of nonsteroidal antiinflammatory drugs. *Semin Arthritis Rheum* **5**, 63–81

Firschein, H E. (1969) Collagen and mineral dynamics in bone *Clin. Orthop* **66**, 212–225

Firschein, H E. & Shill J P (1966) The deter[illegible] in urine [illegible] **14**, 269 [illegible] one matrix [illegible] *n. Invest* **48**, 5[illegible]–600.

Fukuhara, M & Tsurufuji, S (1969) The effect of locally injected anti-inflammatory drugs on the carrageenin granuloma in rats. *Biochem Pharmacol* **18**, 475–484

Høyland, A. & Walløe, L (1975) *Statistikk for medisin, farmasi- og biologistudenter*, Tapir Trondheim

[illegible]

Juva, K. & Prockop, D J (1966) Modified procedure for the assay of ³H- and ¹⁴C-labelled hydroxyproline *Analyt Biochem.* **15**, 77

Kulonen, E & Potila, M (1975) Effect of the administration of antirheumatic drugs on experimental granuloma in rats. *Biochem. Pharmacol* **24**, 219–225

Langeland, N (1975) In vitro studies on collagen metabolism in metaphyseal rat bone A The effect of pre-treatment with oestradiol-17-β [illegible] 775–783

Le[illegible] aspirin *J pharm Sci* **57**, 1238–1240

Lee, K H & Tong T G (1970) Mechanism of action of salicylates. VIII Effect of topical application of retinoic acid on wound healing retardation action of a few anti inflammatory agents. *J pharm. Sci* **59**, 1036–1038

Morton, J J P & Malone, M. H (1972) Evaluation of vulnerary activity by an open wound procedure in rats. *Arch int Pharm* **196**, 117–126

Nordendam, Å & Bang, G (1970) Bone healing after topical application of Apernyl® A histopathologic study in guinea pigs. *Scand J dent Res* **78**, 544–546

Prockop, D J & Udenfriend S (1960) A specific method for the analysis of hydroxyproline in tissues and urine *Analyt Biochem* **1**, 228–239

Raisz, L. G & Koolemans-Beynen, A. R. (1974) Inhibition of bone collagen synthesis by prostaglandin E_2 in organ culture *Prostaglandins* **8**, 377–385

Rø J, Sudmann, E. & Marton P F (1976) Effect of indomethacin on fracture healing in rats. *Acta orthop scand* **47**, 588–599

Sudmann, E (1975) Effect of indomethacin on bone remodelling in rabbit ear chambers. *Acta orthop scand*, Suppl. 160, 91–115

Va[illegible]

Wi[illegible] *Biometrics* **3**, 119–122

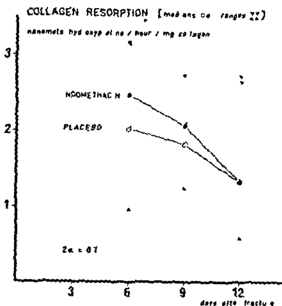


Figure 5 The in vitro resorption of collagen (hydroxyproline) from incubated callus tissue There was no significant difference between indomethacin and placebo treated animals (2α = 0 7)

DISCUSSION

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The present study deals with the in vitro metabolism of the organic component of bone and callus, and it demonstrates clearly that the synthesis and deposition of collagen in callus is higher in the indomethacin treated animals than in their controls. This is consistent with the findings of Aho & Kulonen (1972) and Kulonen & Potila (1975) as far as low doses of indomethacin are concerned, as is to be expected if the primary effect of indomethacin is an inhibition of prostaglandin synthesis (Vane 1971, Raisz & Koolemans Beynen 1974) However, others have reported inhibited collagen synthesis after indomethacin treatment (Winter 1965, Fukuhara & Tsurufuji 1969) and this might be more easily explained in relation to the impaired mechanical properties of the fractures.

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As regards the *in vitro* results of the present study it may be argued that if there is a direct effect of indomethacin on bone cells, the drug may be washed away during preparation of the tissue for incubation. Thus the *in vitro* metabolism might take place without the influence of indomethacin. However, from Figure 1 and Table 1 it will be realized that callus tumour weight and

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REFERENCES

Aalto, M & Kulonen, E (1972) Effect of serotonin, indomethacin and other antirheumatic drugs on the synthesis of collagen and other proteins in granulation tissue slices. *Biochem. Pharmacol* **21**, 2835–2840

Borle, A B & Nichols, G (1960) Metabolic studies on bone in vitro 1 Normal bone. *J biol. Chem.* **235**, 1206–1210

Eschberger, J (1973) Die Beeinflussung der Knochenbruchheilung durch Oxyphenbutazon *Wien med Wschr* **123**, 315–319

Famaey, J-P., Brooks, P M & Dick, W C (1975) Biological effects of nonsteroidal antiinflammatory drugs. *Semin Arthritis Rheum* **5**, 63–81

Firschein, H E. (1969) Collagen and mineral dynamics in bone *Clin. Orthop* **66**, 212–225

Firschein, H E. & Shill J P (1966) The determination of total hydroxyproline in urine and bone extracts. *Analyt Biochem* **14**, 269

Flanagan, B & Nichols, G (1969) Bone matrix turnover and balance in vitro *J clin. Invest* **48**, 595–606.

Fukuhara, M & Tsurufuji, S (1969) The effect of locally injected anti-inflammatory drugs on the carrageenin granuloma in rats. *Biochem Pharmacol* **18**, 475–484

Høyland, A. & Walløe, L (1975) *Statistikk for medisin, farmasi- og biologistudenter*, Tapir Trondheim

Huusko, P J, Nieminen, L H E. & Nieminen L S (1975) The effect of indomethacin on tooth extraction wound healing in rats. *Experientia (Basel)* **31**, 1056–1058

Juva, K. & Prockop, D J (1966) Modified procedure for the assay of ^{3}H- and ^{14}C-labelled hydroxyproline *Analyt Biochem.* **15**, 77

Kulonen, E & Potila, M (1975) Effect of the administration of antirheumatic drugs on experimental granuloma in rats. *Biochem. Pharmacol* **24**, 219–225

Langeland N (1975) In vitro studies on collagen metabolism in metaphyseal rat bone A The effect of pre-treatment with oestradiol-17-β [illegible] 80, 775–783

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aspirin *J pharm Sci* **57**, 1238–1240

Lee, K H & Tong, T G (1970) Mechanism of action of salicylates. VIII Effect of topical application of retinoic acid on wound healing retardation action of a few anti-inflammatory agents. *J pharm Sci* **59**, 1036–1038

Morton, J J P & Malone, M H (1972) Evaluation of vulnerary activity by an open wound procedure in rats. *Arch int Pharm* **196**, 117–126

Nordendam, Å & Bang G (1970) Bone healing after topical application of Apernyl[R] A histopathologic study in guinea pigs. *Scand J dent Res* **78**, 544–546

Prockop, D J & Udenfriend, S (1960) A specific method for the analysis of hydroxyproline in tissues and urine *Analyt Biochem* **1**, 228–239

Raisz, L. G & Koolemans-Beynen, A. R. (1974) Inhibition of bone collagen synthesis by prostaglandin E_2 in organ culture *Prostaglandins* **8**, 377–385

Rø, J, Sudmann, E. & Marton P F (1976) Effect of indomethacin on fracture healing in rats. *Acta orthop scand* **47**, 588–599

Sudmann, E (1975) Effect of indomethacin on bone remodelling in rabbit ear chambers. *Acta orthop scand*, Suppl. 160, 91–115

Vane J R (1971) Inhibition of prostaglandin synthesis as a mechanism of action for aspirin-like drugs. *Nature New Biol* **231**, 232–235

Wilcoxon, F (1947) Probability tables for individual comparisons by ranking methods. *Biometrics* **3**, 119–122.

[illegible], C. A. (1965) Anti-inflammatory testing methods: Comparative evaluation of indomethacin and other agents. *International Congress Series*, Vol. 82, pp. [illegible]. Excerpta medica, Amsterdam.

Correspondence to: Norvald Langeland, Sophies Minde Orthopaedic Hospital, Oslo 5, Norway

ta orthop scand 49, 329–334, 1978

GLYCOSAMINOGLYCAN METABOLISM IN EXPERIMENTAL OSTEOARTHROSIS CAUSED BY IMMOBILIZATION

ERONEN*, T VIDEMAN**, C FRIMAN* & J -E MICHELSSON***

Fourth Department of Med

A study was made of glycosaminoglycan metabolism of articular cartilage in developing experimental osteoarthrosis caused by immobilization of the rabbit knee Cartilage samples from various sites in the knee and hip joints were analysed, samples from the mobile limb serving as controls. The concentration of glycosaminoglycans in the tissue was measured by determinations of hexosamine and uronic acid after prior papain proteolysis and subsequent purification The uptake of ^{35}S-sulphate was used as an indicator of the synthesis rate of sulphated glycosaminoglycans Metabolic changes characteristic of osteoarthrosis, i e, glycosaminoglycan depletion and increased uptake of ^{35}S-sulphate, were found in tibial weight-bearing and femoral condylar cartilages Net synthesis of glycosaminoglycans occurred in the tibial marginal cartilage

Key words osteoarthrosis, articular cartilage, immobilization, glycosaminoglycans, ^{35}S-sulphate

Accepted 6 ii 78

The availability of a progressive and irreversible model arthrosis consistently reproducible in animals and recognizable radiographically is of great importance for the study of the pathogenesis of osteoarthrosis (OA) and for the evaluation of the various forms of treatment The immobilization of the rabbit knee in extension as described earlier (Langenskiold et al 1975) produces a model OA satisfying these demands In this model, 4 days of immobilization caused a marked increase in ^{35}S-sulphate uptake, indicating an accelerated synthesis of sulphated glycosaminoglycans (GAG) in various articular and periarticular tissues of the knee and hip (Videman et al 1976) After 10 days histological and macroscopic changes of a degenerative nature could be seen in the knees Radiologically demonstrable OA was induced by 4 weeks of immobilization, which, if continued for over 7 weeks, produced irreversible restriction of knee joint motion (Videman et al 1977, Michelsson et al 1977)

Characteristic biochemical changes in articular cartilage in OA are an increased water content (Lindahl 1948), an unchanged content of collagen and a decreased content of GAG (Bollet et al 1963 Mankin & Lippiello 1970, 1971) Biochemical information concerning the initial metabolic changes in developing OA is incomplete This may be due to the fact that most experimental OA models are more suitable for the study of advanced than of incipient disease The rabbit model used here produces an OA of a progressive, non-traumatic nature This is

why it is also well suited for the study of the initial metabolic changes associated with the disease A loss of proteoglycans and thus of GAG from the cartilage matrix is generally considered an initial change in OA Hence we decided to study the GAG metabolism of articular cartilage in our experimental OA model with the object of answering the following questions 1 Is the development of OA in this model associated with changes in GAG metabolism similar to those reported to occur in human OA? 2 How early in developing OA are changes in GAG metabolism detectable and what are these changes? 3 Are differences in GAG metabolism discernible in articular cartilage taken from different sites during developing OA?

MATERIALS AND METHODS

The right knees of 16 rabbits older than 9 months were immobilized in extension by means of a plastic splint (PVC) and by bandaging the knee region with Tensoplast® while the hips remained partly movable (Michelsson et al 1977) Six rabbits were used for pilot experiments. Of the remaining ten rabbits, two were killed after 2 6 10 17 and 30 days of immobilization Twenty four hours before they were killed, the animals were given 0 26 mCi/kg ^{35}S-sulphate (carrier free the Radiochemical Centre Amersham, U K.) intramuscularly Samples were taken with a knife both hind legs, tissues from the left leg serving as control material. Samples consisted of articular cartilage from the following sites tibial weight bearing region, tibial margin femoral condyle and femoral head.

The samples were defatted by multiple extractions with acetone, dried to a constant weight at 40°C in a vacuum oven, weighed and digested with papain (Merck 7144) (Wasteson et al. 1972). Proteins were precipitated with 1/3 volume of 40 per cent trichloroacetic acid (TCA). After standing at +4°C overnight the precipitates were centrifuged off and washed once with 10 per cent TCA. The combined supernatants and washings were dialysed against three changes of distilled water at +4°C for 48 hours with stirring The

4 M hydrochloric acid at 100°C. Uronic acid was assayed with m hydroxydiphenyl using D-glucuronic acid as a standard (Blumenkrantz & Asboe-Hansen 1973) ^{35}S radioactivity was measured with a liquid scintillation counter (LKB-Wallac 81000) using automated external standardization for counting efficiency Radioactivities were reported as dpm/μg hexosamine. Statistical significances were evaluated by the Mann Whitney nonparametric test. Differences were considered significant when $P < 0.05$

RESULTS

In the *tibial weight bearing cartilage* the tissue concentrations of hexosamine ($P < 0.005$) and uronic acid ($P < 0.025$) are significantly lower in samples from immobilized joints as compared with the controls (Figure 1a) Tissue concentrations of hexosamine and uronic acid decrease with the period of immobilization the average hexosamine concentration being 50 per cent and the uronic acid concentration 65 per cent of the corresponding control values after 30 days (Figure 1b) On the other hand, specific ^{35}S activity rises, after a small initial decline, indicating an increased synthesis rate of sulphate GAG Specific radioactivities reach mean values approximately 100 150 and 12 per cent higher in immobilized as compared with control cartilages after 10, 1 and 30 days of immobilization respectively (Figure 1b)

In the *femoral condylar cartilage* the metabolic changes are similar to those found in tibial weight bearing cartilage. Concentrations of hexosamine ($P < 0.005$) and of uronic acid ($P < 0.025$) are significantly lower in cartilage from the immobilized joint (Figure 3a) After only 6 days of immobilization the specific ^{35}S activity of immobilized cartilage is approximately 200 per cent higher than in control cartilage and remains markedly elevated throughout the immobilization period (Figure 3b).

In the *tibial marginal cartilage* the changes in GAG metabolism induced by im-

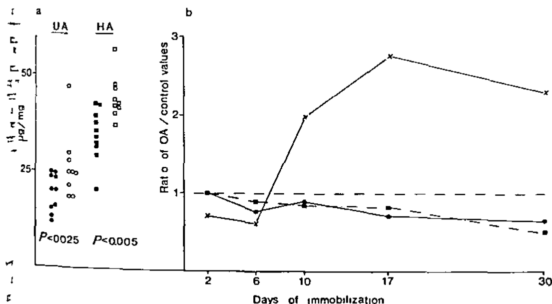


Figure 1 Tibial weight bearing cartilage
(a) Tissue concentrations (μg/mg dry, defatted tissue) of uronic acid (UA)
○ = *control values*
● = *osteoarthrosis values*
and hexosamine (HA)
□ = *control values*
■ = *osteoarthrosis values*
(b) Ratios of osteoarthrosis (OA)/control values of parameters measuring glycosaminoglycan metabolism as a function of immobilization time
● = *uronic acid*
■ = *hexosamine*
× = ^{35}*S activity*

mobilization differ strikingly from those occurring in the cartilages described above. Concentrations of hexosamine ($P<0.01$) and of uronic acid ($P<0.05$) are significantly *higher* in immobilized than in control cartilage (Figure 2a). This increase is distinct after 17 days of immobilization and remains so after 30 days. Specific ^{35}S activity of immobilized cartilage increases progressively with the duration of immobilization, being approximately 7-fold, 9-fold and 12-fold higher than in control cartilage after 10, 17 and 30 days, respectively (Figure 2b).

In the *femoral head cartilage* the concentrations of hexosamine and uronic acid are not affected by immobilization of the knee. Specific ^{35}S activity of cartilage from the immobilized limb, however, is increased about 100 per cent above the control activity after 10 days and remains increased by some 50 per cent throughout immobilization.

The results can be summarized as follows. Immobilization caused an increased specific ^{35}S activity of varying degree in cartilage from all sites studied, i.e., an increased synthesis rate of sulphated GAG. This increase was most pronounced by far in tibial marginal cartilage, where there was a rise in GAG concentration as well, indicating that net synthesis occurred. In tibial weight-bearing and in femoral condylar cartilages immobilization caused GAG depletion indicating that the GAG degradation rate was increased more than the synthesis rate. In femoral head cartilage the GAG concentration was not affected by immobilization.

Figure 2 Tibial marginal cartilage
(a) As Figure 1a
(b) As Figure 1b

Figure 3 Femoral condylar cartilage
(a) As Figure 1a
(b) As Figure 1b

ISCUSSION

ie results show that immobilization of the ibit knee in extension induces changes in IG metabolism in weight-bearing cartilage the knee joint similar to those reported to cur in human OA, i e, decreased GAG concentration and increased synthesis rate of phated GAG Since these alterations of IG metabolism are generally considered ly events in the development of OA, the del arthrosis described appears appropriate the study of the pathogenesis and the atment of OA

Immobilization of the rabbit knee in ension rapidly produces the changes aracteristic of OA in weight-bearing tilage After 10 days the GAG synthesis e increases some 100 per cent and GAG pletion is discernible Besides the rapidity OA induction, other advantages of the sent model arthrosis are its simplicity and non-traumatic nature as compared with gical manoeuvres employed in the production of experimental OA, e g, the Hulth ocedure (Hulth et al 1970, Ehrlich et al 75), partial meniscectomy (Moskowitz et al 73) and anterior cruciate ligament section ond & Nuki 1973, Telhag & Lindberg 72)

The real reasons for the OA changes in nts following immobilization are mostly known Immobilization of the knee in tension causes a continuous compression of weight-bearing cartilages in the joint. us compression may disturb normal ondrocyte function and lead to the changes served It has been found that distraction a joint makes it possible to diminish the A changes in rabbit knee developing during mobilization (Videman & Michelsson 77)

An interesting feature is the initial decline the GAG synthesis rate visible in tibial ight-bearing and femoral condylar car ages after 2 and 6 days of immobilization phenomenon also observed in an earlier idy (Videman et al. 1976) The immolization may disturb chondrocyte function and depress GAG synthesis until degradation of cartilage matrix provides a stronger stimulus leading to increased GAG production by the cells A normal synthetic rate together with incipient degradation of GAG could also lead to diminished uptake of ^{35}S-sulphate as compared with controls.

Cartilage proliferation peripheral to the edges of the joint cartilage on both the femur and the tibia is found after 10 days of immobilization, and after 14 days definite osteophyte formation occurs on the medial aspects of the tibia (Langenskiöld et al, in press) The finding of net synthesis of sulphated GAG in tibial marginal cartilage reported here agrees well with these morphological observations. The opposite changes in GAG concentrations in weight-bearing and marginal cartilage make it important to determine exactly the sampling regions of cartilage, especially in the fully developed disease, when the weight-bearing cartilage may have almost disappeared An important future task appears to be the elucidation of the stimulatory mechanisms underlying the hypertrophy of the marginal cartilage of an osteoarthrotic joint

REFERENCES

Blumenkrantz, N & Asboe-Hansen, G (1973) New method for quantitative determination of uronic acids. *Analyt. Biochem* 54, 484–489

Bollet, A J, Handy, J R. & Sturgill, B C. (1963) Chondroitin sulphate concentration and protein-polysaccharide composition of articular cartilage in osteoarthritis. *J clin Invest* 42, 853–859

Ehrlich, M G, Mankin, H J, Jones, H, Grossmann, B A, Crispen, C & Ancona, D (1975) Biochemical confirmation of an experimental osteoarthritis model. *J Bone Jt Surg* 57-A, 392–396

Hulth, A., Lindberg, L & Telhag H (1970) Experimental osteoarthritis in rabbits. Preliminary report. *Acta orthop scand.* 41, 522–530

Langenskiöld, A., Michelsson, J-E. & Videman, T (1975) Osteoarthritis of the knee in the rabbit produced by immobilization *Scand J Rheum.*, Suppl. 8, 7–8

Lindahl, O (1948) Uber den Wassergehalt des Knorpels *Acta orthop scand* **17**, 134–142

Ludowieg, J & Benmaman, B (1967) Colorimetric differentiation of hexosamines *Analyt Biochem* **19**, 80–88

Mankin, H J & Lippiello, L (1970) Biochemical and metabolic abnormalities in articular cartilage from osteo-arthritic human hips *J Bone Jt Surg* 52-A, 424–434

Mankin, H J & Lippiello, L (1971) The glycosaminoglycans of normal and arthritic cartilage *J clin Invest* **50**, 1712–1719

Michelsson, J-E, Videman, T & Langenskiold, A (1977) Contractures of the knee in provoking osteoarthritis in rabbits by immobilization *IRCS Med Sci* **5**, 61

Moskowitz, R W, Davis, W, Sammarco, J, Martens, M, Baker, J, Mayor, M, Burstein, A H & Frankel, V H (1973) Experimentally induced degenerative joint lesions following partial meniscectomy in the rabbit *Arthr and Rheum* **16**, 397–405

Pond, M J & Nuki, G (1973) Experimentally-induced osteoarthritis in the dog *Ann rheum Dis* **32**, 387–388

Telhag, H & Lindberg, L (1972) A method for inducing osteoarthritic changes in rabbits' knees. *Clin Orthop* **86**, 214–223

Videman, T & Michelsson, J-E (1977) Inhibition of development of experimental osteoarthrosis by distraction during immobilization. *IRCS Med Sci* **5**, 139

Videman, T, Michelsson, J-E & Langenskiöld, A (1977) The development of radiographic changes in experimental osteoarthrosis provoked by immobilization of the knee in rabbits. *IRCS Med Sci* **5**, 62.

Videman, T, Michelsson, J-E., Rauhamäki, R. & Langenskiold, A (1976) Changes in ^{35}S-sulphate uptake in different tissues in the knee and hip regions of rabbits during immobilization, remobilization and the development of osteo-arthritis. *Acta orthop scand.* **47**, 290–298.

Wasteson, Å, Lindahl, U & Hallen, A (1972) Mode of degradation of the chondroitin sulphate proteoglycan in rat costal cartilage *Biochem J* **130**, 729–738

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FAILURE OF AN ELBOW ENDOPROSTHESIS

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In a patient with a severely damaged elbow, the complication of gas gangrene could be controlled without amputating the arm However massive bony defects resulted in a flail elbow joint and an attempt to fit a specially designed endoprosthesis replacement failed Four years post-injury, the flail joint was fused by three bone grafts on three separate occasions These experiences are reported and discussed

Key words elbow endoprosthesis, gas gangrene, sideswipe fracture flail joint, metal hinge joint, massive bony defect and arthrodesis

Accepted 29.xi 77

A specially designed hinge joint was inserted into an elbow joint which had suffered a severe crush injury and subsequently developed gas gangrene After only one month, the procedure failed The difficult and instructive reconstruction program is described here

CASE REPORT

A 23 year-old male machinist, whose right elbow had been broken, was admitted to our clinic on August 19, 1965 A fetid secretion which resembled meat juice was dripping from the roughly sutured wound (Figure 1) An X-ray showed a comminuted sideswipe fracture (Watson Jones 1960) and small gas bubbles (Figure 2). As the complication of gas gangrene was suspected, strict brushing and debridement were performed immediately with administration of antisera and antibiotics Clostridium welchii was cultivated from the secretion.

After a week, a split thickness skin graft was performed on the healthy granulation wound. However, the patient's elbow had become a flail joint, due to massive bony defects, and had to be supported by a light splint. Fortunately the gas gangrene could be controlled without amputation Thereafter reconstructive procedures began with a pedicle skin graft from his right chest wall on September 9, 1966



Figure 1 Severely injured right elbow (August 19, 1965)



Figure 2 X-ray of right elbow (August 19, 1965)

On November 18 1966, a specially designed hinge joint made of chrome nickel alloy was inserted into the elbow joint (Figure 3) 22 A is an excellent stainless steel (Cr 19–21 Ni 21–23 Mo 1 5–2 5 C<0 1, Cu 1 5–2 5) which was introduced by Prof Saburo Iino and Prof Yunoshin Imai in 1951 (Iino & Imai 1951) and has since been used clinically in Japan

Postoperatively, the range of passive motion was from 0 to 80° However a hematoma and a fistula subsequently appeared and staphylococcus aureus was detected On December 19 1966 the metal joint appeared through the ruptured skin and had to be removed Thus, the first attempt to reproduce a movable elbow joint had failed

On January 27 1967, the second attempt involving a functional arthrodes...

...performed with bone from the right fibula (Figure 4) and ilium and from the left tibia and ilium On February 29 1969, when he

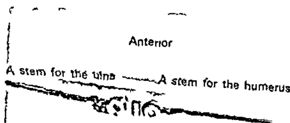


Figure 3 A specially designed hinge joint made of chrome nickel alloy (22 A)



Figure 4 X ray of the right elbow after a fibular bone graft



Figure 5 X ray on August 9 1977 The elbow had united in a functional position.



Figure 6 Making a powerful grip on August 9 1977

threw a snowball his left tibia fractured and was placed in a plaster cast which was removed after 2 months In the meantime the elbow had united in a functional po...

DISCUSSION

Nowadays gas gangrene is a rare complication Only two cases with this complication have been admitted to our clinic during the past 15 years Primary wound procedures should be strictly adhered to in order to exclude this complication

In the case of massive bony defects, the most satisfactory results seemed to be achieved by an endoprosthetic replacement To develop a suitable endoprosthesis of the

bow joint, Roger Dee began a design ı in London in 1968 (Dee 1976) In reported here, a metal hinge joint for elbow made of chrome nickel alloy (22-A) as inserted However, this metal joint iffered from three deficiencies firstly, it was ot designed for use with acrylic cements, econdly, its straight rod stem was torsionally nstable in the reamed bone marrow cavity, nd thirdly, it was not designed to reproduce he triceps mechanism Unfortunately, therefore, our first attempt at an elbow endoprosthesis failed

Although the gas gangrene could be controlled, the subsequent reconstructive procedures induced a post-operative infection These unfortunate double infections forced us to postpone any further reconstructive procedures for 4 years

However, the patient is at present working comfortably

REFERENCES

Dee, R (1976) Total elbow replacement *A.A O S Symposium on Osteoarthritis* pp 233–245, C V Mosby Co, Saint Louis

Iino, S & Imai Y (1951) Study on metallic material treatment of fracture *Clin Surg* 6, 451–453 (Japanese)

Watson Jones, R (1960) *Fractures and joint injuries* Vol 2 4th ed pp 552–553, E & S Livingstone Ltd, Edinburgh

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COMPRESSION OF THE SUPRASCAPULAR NERVE AFTER FRACTURE OF THE SCAPULAR NOTCH

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A 32-year-old man with a fracture of the scapular notch associated w[illegible] lesion of the suprascapular nerve is reported A nerve decompress[illegible] operation was performed 20 months after the injury with relief of pa[illegible] possibility that residual disability following a fracture of the scapula ca[illegible] due to a lesion of the suprascapular nerve is underlined. The value of X-[illegible] examination with projections visualizing the notch and diagnostic b[illegible] anaesthetic block of the nerve passi[illegible]g through the notch are emphas[illegible] Primary wide resection of the scapular notch is a preferable procedure f[illegible] venting recurrence of nerve compression symptoms.

Key words scapula fracture suprascapular nerve compression ne[illegible] decompression operation

Accepted 24 i 78

of the scapula is uncommon and when it occurs it is often one among multiple injuries caused by a serious trauma (Muller-Farber 1976, Rowe 1963, Zdravkovic & Damholt 1974) The scapular notch may be involved in fractures through the superior lateral angle of the scapula (DeCoulx et al 1956, Edeland & Zachrisson 1975), and is sometimes associated with a lesion of the suprascapular nerve This mixed sensory and motor nerve originates from the fourth, fifth and sixth cervical nerves, runs through the scapular notch and ramifies to the supraspinatus and infraspinatus muscles, parts of the humeroscapular and acromioscapular joints and to the scapula itself

CASE REPORT

A 32-year-old man injured his left shoulder [illegible] traffic accident X ray examination showed a c[illegible] minuted scapula fracture (Figure 1) which he[illegible] with immobilization of the shoulder During [illegible] next 20 months he was treated for resid[illegible] shoulder girdle symptoms with various form[illegible] physical therapy and injections but without [illegible]provement.

Arthrography and electromyographic exam[illegible]tion (EMG) 15 months after the injury w[illegible] negative

Examination 5 months later revealed pa[illegible] and restricted mobility of the shoulder toge[illegible] with weakness of the shoulder girdle muscles [illegible] tenderness in the region of the scapular no[illegible] Local anaesthetic block of the suprascapular ne[illegible] in the notch relieved the pain.

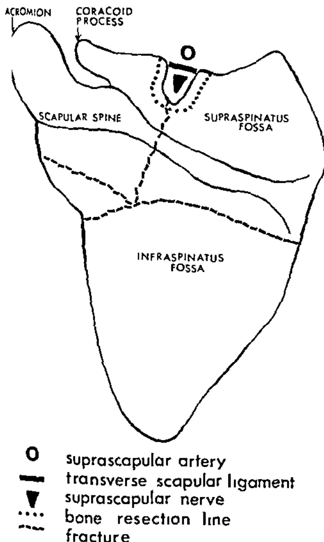


Figure 1 Dorsal view of the left scapula shows the comminuted fracture and the scapular notch with the wide resection of bone

An operation was performed 20 months after ›e injury through an incision along the upper order of the scapular spine extending the dissec-on beneath the supraspinatus muscle to the otch, where the suprascapular nerve was seen to e surrounded by a mass of callus. The nerve ppeared to be taut and swollen in the proximal irection but thin and atrophic distal to the notch he transverse scapular ligament was sectioned nd removed, the nerve released and using a small iminectomy rongeur the notch was widely esected (Figure 1).

The considerable pain in the shoulder was lieved by the operation, but some tenderness of ›e muscles lasted for several months.

DISCUSSION

Suprascapular nerve entrapment occurs after overstretching of the nerve in the scapular notch with resultant swelling of the nerve which leads to a pain-swelling cycle

Severe forward flexion injury of the shoulder, especially protraction and forward rotatory movement of the scapula, tether the nerve in the fibro-osseous tunnel of the notch (Rask 1977) Isolated mechanical compression of the suprascapular nerve may give shoulder pain without an obvious cause (Komar 1976).

Edeland & Zachrisson (1975) found, among 18 fractures of the scapula, involvement of the scapular notch in two patients, and in one of these there was injury to the suprascapular nerve They recommended that a simple antero-posterior projection, with the tube angled 15–30° caudally visualizing the scapular notch, should be included as a routine in the X-ray examination of patients with fractures through the superior lateral angle of the scapula By conventional X-ray techniques with antero-posterior and lateral projections the notch is not clearly visualized

Suprascapular nerve lesion in our patient was not suspected until the primary roentgenograms were compared with those from the re-examination Diagnostic suprascapular nerve block by infiltrating local anaesthetics at the scapular notch (Gordh 1969, Edeland & Stefánsson 1973) relieved the shoulder pain TV-monitored positioning was used to facilitate both the X-ray examination and the nerve block

Electromyographic examination of the supraspinatus muscle may show obvious signs of suprascapular nerve involvement (Edeland & Zachrisson 1975) In our patient EMG performed 5 months before the operation showed no pathological findings, but the physical examination, the X-ray findings and the effect of the nerve block suggested involvement The operation confirmed the diagnosis of nerve compression

In this nerve decompression operation [illegible]ally only the transverse scapular ligament is sectioned. However, we agree with Rask (1977) that primary wide notch resection is a preferable procedure preventing recurrence of nerve compression symptoms.

This case draws attention to the possibility that residual disability following a fracture of the scapula can be due to a lesion of the suprascapular nerve where it passes through the scapular notch

REFERENCES

[illegible]

E[illegible] the suprascapular nerve in reduction of acute anterior shoulder dislocation *Acta anaesth scand* 17, 46–49

Edeland, H G & Zachrisson, B E (197[illegible]) Fracture of the scapular notch associated with lesion of the suprascapular nerve. *Acta orthop scand* 46 758–763

Gordh T (1969) Suprascapular nerve block *Illustrated handbook in local anaesthesia* ed Ejnar Eriksson pp 81 Munksgaard, Copenhagen

Komar, J (1976) Wichtige Ursache des Schulterschmerzes Incisura scapulae syndrom *Fortschr Neurol Psychiat* 44 644 648

Muller-Farber, J (1976) Die Skapulafrakturen Konservative oder operative behandlung *Unfallheilkunde* 79 295–303

Rask, M R (1977) Suprascapular nerve entrapment A report of two cases treated with suprascapular notch resection. *Clin. Orthop* 123, 73–75

Rowe C R (1963) Fractures of the scapula *Surg Clin N Amer* 43 1565–1571

Zdravkovic, D & Damholt, [illegible] (19[illegible]) Comminuted and severely displaced fractures of the scapula *Acta orthop scand.* 45 60–65

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INTERLAMINAR ATLANTO-AXIAL FUSION FOR INSTABILITY

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At the Departments of Neurosurgery and Orthopaedic Surgery in Odense 36 patients were treated with atlanto-axial interlaminar fusion The operation was performed jointly by the neurosurgeon and orthopaedic surgeon, working as a team, using a specially developed technique Two bone grafts from the iliac crest were shaped with grooves for the two laminae, and fixed with wire on the right and left side Postoperative immobilization in a Minerva jacket was maintained for 3 months and a plastic collar was worn for another 3 months

Twenty-one patients had odontoid fractures five of them with pseudarthrosis. Ten had atlanto-axial instability caused by rheumatoid arthritis. The instability was horizontal in seven cases, with a mean distance of 12 mm from the odontoid process to the anterior arch of the atlas. Five patients had vertical dislocation with the apex of the odontoid process protruding 8 mm (mean) cranially to the foramen magnum and eight had cord signs. Two patients had an os odontoideum with instability after trauma, and three had other lesions.

At follow-up, at least 1 year after the operation, all fusions were solid, and all fractures but one had healed. The rheumatoid patients had achieved great relief of symptoms with minimum restriction of movement in the cervical spine The indications for operation on patients with rheumatoid arthritis are very restrictive

Key words atlanto-axial instability, rheumatoid arthritis, atlanto-axial instability, atlanto-axial interlaminar fusion

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Several surgical methods for stabilizing traumatic as well as non-traumatic atlanto-axial instability have recently been published and are being used with increasing frequency Indications as well as methods have differed widely, and there has also been an appreciable difference in the results.

At the Odense Hospital we have developed, by collaboration between orthopaedic surgeon (KHS) and neurosurgeon (JH) our own technique which has been used without modification since 1966 The indications, the technique itself, and the results will be reported below

PATIENTS AND METHODS

From November 1966 to April 1975, a total of 36 patients underwent atlanto-axial fusion. There were 21 males and 15 females with ages ranging from 10–78 years (Table 1) Twenty-one had fracture or pseudarthrosis of the odontoid process, 10 atlanto-axial instability because of rheumatoid arthritis, and two an unstable os odontoideum [illegible] (Grisel 1930), and one patient had hangman's fracture which normally we treat conservatively (Termansen 1974).

In the course of the study period the number of operations increased (Table 2), reflecting an increased surgical activity Half the patients had cord signs

Fracture and pseudarthrosis of the odontoid process Among the 21 males, 10 were between 17 and 24 years of age Five of the male group had pseudarthrosis and had their operation an average of 7 (3–17) months after the accident Fourteen fractures had been sustained in traffic accidents Six had not been recognized primarily, and three developed pseudarthrosis One patient had an operation for a fracture of the lower leg before the fracture of the odontoid process was diagnosed In 12 instances the diagnosis was not made until tomography was done We used our previously reported classification into *high* and *low* fractures (Husby & Sørensen 1974) Seventeen fractures were high and four low, all were unstable High fractures are unstable more often than low ones Seven were pre-treated with cranial traction, four with bed rest on a double mattress with backward bent head, and eight with plastic collars. A number of low, stable fractures were treated conservatively

A total of 25 patients had been involved in accidents. Nine had concussion and two contusion of the brain, seven had cord signs, and nine other injuries (4 extremity fractures, 4 cranial fractures, [illegible] amounted to up to 15 mm and the angulation up t 37° Several patients had considerable angulatio as well as dislocation.

Table 1 Sex ratio, age distribution, and diagnoses in patients treated with posterior atlanto-axial spondylodesis

Age, years	10–49	50–78
21 males	17	4
15 females	2	13
Odontoid fracture		
pseudarthrosis	13	8
[illegible] arthritis	1	9
Os odontoideum + trauma	2	—
Other conditions	3	—

Rheumatoid arthritis At operation, the t patients averaged 63 years of age (range 45–7 and the mean duration of rheumatoid arthritis w 21 years Seven had been on a lengthy course cortisone medication, eight had cord signs cerebro-vascular deficit symptoms, and this w decisive in the indications. From Table 4 it apparent that radiology showed considerab horizontal instability, the distance between t anterior edge of the *odontoid process* and t anterior arch of the atlas being 6–22, mea 12 mm Five had vertical dislocation, the tip of t odontoid process protruding 3–15, mean 8 mm, above the level of the foramen magnum (McRae line) which it should not normally exce Radiology, often tomography, revealed in most these patients widespread destructive a degenerative changes of the odontoid process a the region on the whole. All ten patients ha extensive arthritic sequelae and degeneration the cervical discs and small joints, typical rheumatoid arthritis (Rana et al. 1973). All ha severe rheumatoid arthritis with severe deform of the extremity joints, and all were on d sabl ment or old-age pension

Preoperatively three patients were treated w backward bent head on a double mattress, and fi were treated for a varying period of time with supporting neck collar (Camp model). Th rheumatoid patients were subjected to operatio only on very strict indications, viz., neurologi deficits or radiological changes so severe that the was a risk of a progressive or total cord lesi Patients with less severe symptoms and si were treated conservatively

Table 2 Classification into periods showing that the number of fusion operations has been increas

	Odontoid fracture or pseudarthrosis	Rheumatoid arthritis	Other conditions	Total
Nov 15th 1966–1968 incl.	4	—	—	4
1969–1971 incl	7	2	3	12
1972–May 1975 incl	10	8	2	2[illegible]
Cord signs	5	8	2	15

ble 3 Dislocation and angulation in fracture or pseudarthrosis of the odontoid process in 21 patients (cf Table 5)

slocation of odontoid ocess	Forward	Backward	Right	Left	Total
umber of patients iteral dislocation	*9*	*5*	*1*	*2*	*15*
mean mm	5	7	5	4	
range mm	1–10	3–13	—	2 6	
umber of patients igulation (degrees)	*3*	*9*	*3*	*3*	*17*
mean	25°	19°	10°	6°	
range	20–30°	5–37°	5–16°	3–12°	
			Normal position 3		

Table 4 Data for 10 patients with rheumatoid arthritis

	Dislocation of odontoid process		
	Horizontal	Vertical	Horizontal + vertical
0 patients	5	1	4
lean age 63 years	54–70	63	48–72
lean duration of rheumatoid arthritis (years)	24	17	21
No of pts. having cortisone medication (6 mo– 21 yrs.)	3	1	3
Cord or neurovascular deficit signs	5	1	2
Distance (max) from ant. arch of atlas to odontoid process	13	—	11
Range, mm	6–22		8–13

METHODS

When the distance between the atlas and odontoid process was increased, the patient was pre-treated with backward bent head on a double mattress, the upper mattress reaching only to the shoulders. The decision regarding the indications was made jointly by the orthopaedic surgeon and the neurosurgeon and the operation itself was performed by both surgeons working as a team All the staff must be made aware of the risk caused by the instability

The patient is anaesthetized and intubated supine, and cranial traction is established (Blackburn tongs) to be on the safe side and to facilitate reduction Thereafter, the patient is turned over to lie prone, his head on a special head rest fastened to the operating table (Figure 1), and his trunk on a special table used in operations for slipped disc, the median part of the trunk being free. The head is positioned bent 5–10° backward The neurosurgeon exposes, through a midline incision, the posterior aspect of the atlantic and axial arches and occipital bone

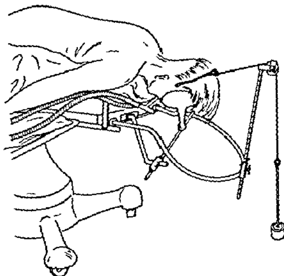


Figure 1 The patient's position on the operating table, his head on the specially constructed head rest Cranial traction has been established

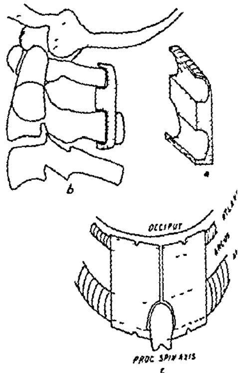


Figure 2 The shaping of the grafts and their placement

behind the foramen magnum and cuts off the compact bone on the posterior aspect of the two arches and at the base of the spinous process of the axis A spun, stainless steel wire is passed cranio-caudally anteriorly to the arches of the atlas and axis on the right side and another one on the left

The orthopaedic surgeon removes from the iliac crest posteriorly on the left two bone grafts, about 2 cm wide and about 3 cm long, as required according to measurements, and comprising the lamina externa, half the crest, and underlying spongy bone In the presence of osteoporosis or slender bones, the lamina interna is included as well In each graft a groove is shaped just beneath crest (Figure 2) to fit the atlantic arch, so that the crest firmly grips the upper edge Farther down, a groove for the axial arch is made, and the bony prominence between the two grooves on the graft fits the distance between the two arches and projects between them A corner distally-centrally in each graft is cut off at the level of the spinous process of the axis. The middle of the upper and lower edges is notched to accommodate the steel wires which are now tied, on the right and on the left side, so that the grafts are pressed forward into contact with the two arches. Two strong needle holders are used to tighten the wires The free ends of the steel wire from the right and left side are tied transversely, both above and below the spinous process. This presses the grafts even more firmly, and the two arches cannot be pulled towards each other The wounds are closed The patient is laid supine in bed with sand bags at the sides of his head after the cranial traction on both been removed The patient is taken out of bed to stand twice daily, but is not allowed to move his head After the sutures have been removed on the 10th day, a felt-padded Minerva jacket is applied Three months after the operation the patient is re-admitted for removal of the plaster cast and lateral tomography If union has occurred, he is discharged with a plastic collar to be worn for 3 months and after radiography during anterior and posterior bending to secure stability he is given brief instructions for training of the cervical and occipital muscles One year after the operation he attends a clinical and radiological follow-up examination

In two patients with fracture of the odontoid process, C_3 was included in the fusion (congenital synostosis of C_2, C_3, and C_4, fracture of lateral occipital condyle). In 21 cases the grafts consisted of only half the thickness of the iliac crest and in 15 cases full thickness iliac bone was used Seven of these latter patients had rheumatoid arthritis and six had been treated with steroids two of them had quite severe osteoporosis In few very slim patients a mini-Minerva jacket was applied with plaster plates down the anterior and posterior aspect of the trunk. All plaster casts


A


B

Figure 3 Autopsy specimen of a cervical spine treated by spondylodesis 4 months before the patient died The grafts are solidly fused (cf text)
A Lateral view
B Oblique postero-lateral view

were padded with felt Five patients with rheumatoid arthritis wore the supporting neck collar for 4–9 months and one for 35 months (severe osteoporosis and a long course of cortisone medication.

RESULTS

Thirty-five patients were seen at follow-up 1–5, mean 2 years 2 months, after the operation. A woman, aged 54, and treated with steroids for 15 years because of rheumatoid arthritis, died 4 months after the operation of pulmonary embolism, preceded by two attacks of pneumonia At autopsy the upper part of the cervical spine was removed There was solid union at the site of the spondylodesis (Figure 3)

All the spondylodeses had united (Figures 4, 5) In one patient odontoid non union was still present 13 months after the operation, but this was of no clinical significance, as the spondylodesis was solid. In a 77-year-old patient only the posterior

Table 5 Position of odontoid process after healing of the spondylodesis (cf Table 3)

Dislocation of odontoid process	Forward	Backward	Right	Left	Total (preop)
No. of patients	1	2	0	0	3 (14)
Lateral dislocation (mm)	3	2 6	—	—	
No. of patients	1	8	1	3	13 (14)
Angulation, mean	19°	19°	6°	6°	
Angulation range	—	18 27°	—	6–12°	

Normal position 8 patients (preop 3 patients).



A



A



B



B

Figure 4 70-year-old woman with a 20-year history of non steroid treated rheumatoid arthritis
A Lateral view prior to operation The distance between the odontoid process and the anterior arch of the atlas is 14 mm
B Lateral view 35 months after the operation Spondylodesis solidly healed Odontoid process in the normal anatomical position

Figure 5 22 year-old man with a high [illegible] fracture of the odontoid process
A. Lateral view 25 months after the [illegible] shows solid healing of the spondylodesis as [illegible] as odontoid process The ondontoid process is [illegible] backwards 15°
B Anteroposterior view illustrating the [illegible] of the steel wires

uarter of the odontoid fracture had united 1 ear after the operation In one case one of the grafts took almost 2 years to unite with the atlas, but this did not involve symptoms r a prolonged period of wearing a collar

In the odontoid fractures considerable improvement of the position was obtained (Table 5) and in five cases there was a ormal anatomical position Sixteen of the atients with odontoid fracture were ymptom free, four had mild, periodical atigue or pain at the back of the neck, and ne had constant pain (This was a 77-year-ld woman in whom the odontoid process ad been tilted backwards 24°, and the racture had united only in the posterior one-uarter She exhibited severe spondylosis round the 5th disc and osteoarthrosis in all mall joints as well as the joint between C_1 nd C_2) There were no sequelae to eurolesions. Seventeen patients had gone ack to work an average of 7 months after he operation, while four were still on ension

Six of the nine rheumatoid arthritics seen t follow-up had been largely relieved of their ymptoms of atlanto-axial instability Two ad mild pain periodically or a feeling of tiffness The cord signs had disappeared or onsiderably decreased except in one case Tomography showed solid healing of the pondylodesis in all The horizontal dislocation of the odontoid process had been abolished in five, and in the others the mean distance from the odontoid process to the anterior arch of the atlas was 7 mm (5–10) as compared with 11 mm prior to the operation Central dislocation had been reduced by 2–4 mm in two patients, but was unchanged in the others In one patient the odontoid process was tilted backwards 20° as against 23° before the operation (in relation to a plane through the anterior and posterior atlantic arches) Two patients died 15 and 41 months after the operation, so that a total of three of these ten patients in a fairly poor condition died, all of causes unrelated to the atlanto-axial instability

The spondylodeses had healed solidly in five patients with various more uncommon diseases, and all of them were working One with an os odontoideum and instability following trauma still had pain at the back of the neck and in the left arm as well as disturbances of sensibility down to the ring and little fingers The spondylodesis had healed, with the odontoid bone tilted forwards 18° and displaced 5 mm to the right and 7 mm forward together with the entire axis in relation to C_1 At the operation 7 months after the trauma it had been impossible to improve the position The spondylodesis was found to have extended to C_3 2 years after the operation

Mobility in the cervical spine in young patients having an otherwise normal cervical spine was in fact normal, but in elderly patients with degenerative changes it was restricted, in a few to a troublesome extent

There were no infections, problems of wound healing, or thromboembolic complications. There were no calcifications of the soft tissues surrounding the spondylodesis, no steel wires had broken, and there were no local symptoms. In one case the wing of the iliac bone fractured 2 weeks after the operation, close to the donor site, but there were no late sequelae

DISCUSSION

Indications After conservative treatment of unstable odontoid fractures there is a great risk of non-union In cases of high fractures as many as 36 per cent do not unite (Anderson & D'Alonzo 1974), but regardless of the site of the fracture, non-union is common (Schatzker et al 1971 61 per cent, Ramadier et al. 1976 35 per cent) In non-dislocated fractures Schatzker et al. demonstrated non-union in 42 per cent, in posterior dislocation in as many as 89 per cent. The frequency of life-threatening complications in cases of instability has not been reported, but a few authors have described

such cases (Hentzer & Schalimtzek 1971) *Recent publications have therefore justly* advocated fusion in atlanto-axial instability, if a reliable result is not obtained by conservative treatment, as this can prevent life-threatening complications to which these patients are easily exposed in modern road traffic (Schatzker et al 1971, McGrav & Rusch 1973, Anderson & D'Alonzo 1974, and others) In doubtful cases we have assessed the stability by forward and backward bending while manual traction is exerted on the skull by an experienced orthopaedic surgeon or neurosurgeon during fluoroscopy

Atlanto-axial instability has been demonstrated in 25 per cent of hospitalized patients with rheumatoid arthritis (Conlon et al 1966), and fatal cord compression is more common than previously assumed (Mikulowski et al 1975) Among 130 patients with rheumatoid arthritis and atlanto-axial instability, but without neurological deficit, Smith et al (1972) found 5–14 years later that 52 had died, 4 had cord signs, and 6 had symptoms of vertebral artery ischaemia As the instability most often gives rise to symptoms at the most severe stage of the disease in very disabled patients, most authors reserve operation for patients who develop cord or vascular deficit symptoms or increasing pain and stiffness despite conservative treatment (Meijers et al 1974, Ferlic et al 1975, Thomas 1975, Brattstrom & Granholm 1976, Jones & Kaufmann 1976) *especially if the symptoms progress or if* acute, neurological episodes occur (Rana et al 1973) We have acted on similar principles In the presence of severe osteoporosis, we have abstained from operation

Technique Gallie (1939) set down the principles for stabilizing instability in the cervical spine, viz, fixation of the two involved vertebrae by steel wires and simultaneous insertion of bone grafts from the ileum or tibia Gallie used this principle with increasing frequency for injuries in all parts of the cervical spine It has later been designated as a Gallie atlanto-axial fusion, although he did not accurately describe th *technique or report the results.* With mo modifications, and with widely differe postoperative immobilization (cranial tractio Minerva jacket, neck collar, etc) it h been used by many workers (Simmonds & Fielding 1967, Schatzker et al. 19 McGrav & Rusch 1973, Anderson & D'Alon 1974, Fielding et al 1976 Ramadier et a 1976)

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The *results* of atlanto-axial fusion by single bone graft (Gallie fusion) are said to good, with few complications and rather fe cases of non union Simmonds & Field (1967) obtained union in all their 35 ca Schatzker et al (1971) in 13 out of 15 (tw in 9 cases the fracture of the odontoid proce did not heal, but this was of subordinate im portance), McGrav & Rusch (1975) in 14 o of 15, and Anderson & D'Alonzo (1974) in out of 18 cases. Ramadier & Aleon (19 *obtained healing in* 93 per cent of 90 opera cases (64 atlanto-axial, 25 occipito-cervica and Fielding et al. (1976) in 44 out of 4 atlanto-axially fused and in 9 out of 1 occipito-cervically *fused cases.*

After occipito-cervical fusion Patte & Ro (1969) reported healing in 12, Newman & Sweetnam (1969) in 9 and Grantham (19 in 8 out of 9, whereas Meijers et al (197 had healing in 11 out of 12 operated patien (one patient died postoperatively). Brattstro & Granholm (1976) have reported exceller results in 21 out of 28 operated patients in whom they used acrylic *bone cement* and occipito-cervical steel wire fixation.

ı the various materials the position of the ɒtoid process and axis in relation to the s has not been systematically described r healing of the spondylodesis By our uuque the desired position is obtained ıuse of the interposition of the graft veen the arches of C_1 and C_2, and extra ılization is afforded by the two grafts ɔing an angle with each other

lur material confirms that the surgical tment of atlanto-axial instability can be lered devoid of complications and its ılt reliable However, the indications for operation will remain strict in the case of ients with rheumatoid arthritis owing to r already poor prognosis

·'ERENCES

erson, L. D & D'Alonzo, R T (1974) 'ractures of the odontoid process of the axis. ' *Bone Jt Surg* 56-A 1663–1674

tstrom H & Granholm, L (1976) Atlanto-xial fusion in rheumatoid arthritis. *Acta rthop scand* 47, 619–628

lon P W Isdale I C. & Rose, B S (1966) theumatoid arthritis of the cervical spine *Inn rheum Dis* 25, 120–126

ting J W, Hawkins, R J & Ratzan S A 1976) Spine fusion for atlanto-axial instability ' *Bone Jt Surg* 58-A, 400–407

ıc, D C., Clayton, M L, Leidholt, J D & Gamble W E. (1975) Surgical treatment of the symptomatic unstable cervical spine in rheumatoid arthritis *J Bone Jt Surg* 57 A, 349–354

lie W E (1939) Fractures and dislocations of the cervical spine *Amer J Surg* 46, 495–499

ıntham, S A., Dick H M, Thompson, R C & Stinchfield F E (1969) Occipitocervical arthrodesis. *Clin. Orthop* 65, 118–129

sel, P (1930) Enucleation de l'atlas et torticollis naso-pharyngien *Presse méd* I, 50–53

ıtzer L. & Schalimtzek, M (1971) Fractures and subluxations of the atlas and axis. *Acta orthop scand* 42, 251–258

Husby, J & Sørensen, K. H (1974) Fracture of the odontoid process of the axis. *Acta orthop scand* 45, 182–189

Jones, M W & Kaufmann, J C E (1976) Vertebrobasilar artery insufficiency in rheumatoid atlantoaxial subluxation *J Neurosurg* 39, 122–128

Kelly, D L, Alexander, Jr, E, Courtland, Jr H. D & Smith, J M (1972) Acrylic fixation of atlanto-axial dislocations. *J Neurosurg* 36, 366–371

McGrav, R W & Rusch, R M (1973) Atlanto-axial arthrodesis *J Bone Jt Surg* 55 B 482–489

Meijers, K A. E, van Beusekom G Th, Luyendijk, W & Duijfjes F (1974) Dislocation of the cervical spine with cord compression in rheumatoid arthritis. *J Bone Jt Surg* 56-B, 668–680

Mikulowski, P, Wollheim, F A, Rotmil, P & Olsen, I (1975) Sudden death in rheumatoid arthritis with atlanto-axial dislocation *Acta med scand* 198, 445–451

Newman, P & Sweetnam, R (1969) Occipito-cervical fusion *J Bone Jt Surg* 51 B, 423–431

Patte, D & Rose, B (1969) Arthrodeses cervico-occipitales. *Rev Chir orthop* 55, 675–682

Ramadier, J O & Aleon, J F (1975) Le traitement par arthrodese des instabilités de la région cranio-rachidienne *Ann Chir* 29, 727–741

Ramadier, J O, Aleon J F & Servant, J (1976) Les fractures de l'apophyse odonoide *Rev Chir orthop* 62, 171–189

Rana N A, Hancock, D O, Taylor, A R & Hill, A G S (1973) Atlanto-axial subluxation in rheumatoid arthritis *J Bone Jt Surg* 55-B 458–470

Schatzker, J, Rorabeck, C H & Waddell, J P (1971) Fractures of the dens (odontoid process) *J Bone Jt Surg* 53 B, 392–405

Simmonds, E H & Fielding J W (1967) Atlanto-axial arthrodesis. *J Bone Jt Surg* 49-A 1022

Smith, P H, Benn R T & Sharp J (1972) Natural history of rheumatoid cervical luxation *Ann rheum Dis* 31, 431–439

Termansen N B (1974) Hangman's fracture. *Acta orthop scand* 45, 529–539

Thomas, W H (1975) Surgical management of the rheumatoid cervical spine *Orthop Clin N Amer* 6, 793–800

respondence to K. Harry Sørensen M.D Department of Orthopaedic Surgery, Odense Hospital, 0 Odense, Denmark.

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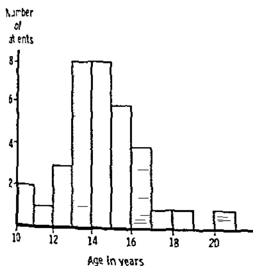
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igure 1 Histogram showing the age distribution f patients at the time of operation (35 patients)

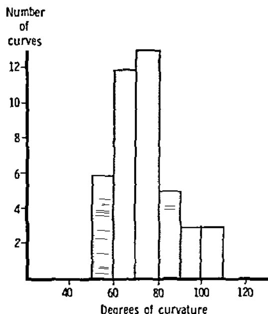


Figure 2 Histogram showing the distribution of curve angles before operation, measured by the method of Cobb

rches. A final distract on of the H ...

... s ambulated The brace is worn constantly for 1 year For an additional 6 months a upporting abdominal corset is used. One and a alf years after the operation the patients are llowed to move about freely and to participate in hysical activities.

ESULTS

he patients' ages at the time of operation re shown in Figure 1 The mean age was 14 ears. One patient was operated upon after essation of growth – 21 years of age The nean period of observation before the peration was 4 years. For patients with dolescent idiopathic scoliosis, the mean period of observation before the operation was 2½ years. Some of the patients were observed initially at other orthopaedic clinics.

Preoperatively the Milwaukee brace had been used in 23 of the 35 patients. The preoperative curve varied between 51 and 106° the average being 74° (Figure 2) The mean correction afforded by the operation was 33°, corresponding to a correction of 45 per cent This correction varied from 13 to 61 per cent In the 1st year after the operation the average loss of correction was 8° varying from 0 to 22° In six cases the hook slipped one notch down the Harrington rod This in four cases

Table 2 Results in 42 curves

	Degree			Percentage of preoperative curve		
	min	max	average	min	max.	average
nitial correction	10	51	33	13	61	45
oss in Milwaukee brace during post operative year	0	22	8			
oss after removal of brace	0	9	0 7			
Total loss	0	22	8 7			
inal maintained correction	1	46	24	1	51	33



A Before operation B On the day of the operation C 4½ months after the operation

Figure 3 13 year old girl with an idiopathic scoliosis
The initial curve measured 66° The curve was corrected to 29° 4½ months later the curve had relapsed to 40° Note the changing position of the lower hook on the neural arch

contributed to a loss of correction from 11 to 22° during the 1st year In other cases the lower hook changed its position on the neural arch and this may have contributed to a loss of correction (Figure 3) After the 1st year the loss of correction was minimal averaging 0 7°

At the final follow up from 1½ to 4½ years after the operation average 2¾ years, a mean correction of 25° or 33 per cent had been obtained (Table 2)

Complications were few One patient had a transient paresis of the right leg and another patient a transient sensory disturbance Pseudarthrosis was not observed In four cases the initial correction was minimal because the scoliotic curve was very rigid This applied to three cases of idiopathic scoliosis and to one case of congenital scoliosis only In one case an idiopathic scoliosis a correction of only 11° was obtained During distraction the upper neural arch fractured so that the hook had to be placed one vertebra higher

DISCUSSION

An initial correction of 45 per cent corresponds with that obtained in materials such as Pigott s (1976) and Bjerkreim s ([illegible]) while in other materials a larger initial correction was obtained (Nordwall (19[illegible]), [illegible] per cent Goldstein (1969) 64 per cent and Dickson & Harrington (1973), 64 per cent

: reason for a larger initial correction may a smaller initial curve, which means lesser dity and lesser rotation and makes a ter correction possible (Goldstein 1969) refore it is recommended that the patients sent to a qualified orthopaedic surgical artment at an early stage

. certain loss of correction after the ration will occur as a result of growth of spine The postoperative loss of correc- reported varies (Goldstein (1969), 3 2 per t, Leider et al (1973), 5°, Nachemson 76) 6°, Bjerkreim (1976) 6 5°, and kson & Harrington (1973), 8°) In this erial the loss averaged 8 7°

There were two essential reasons for loss correction, descendance of the upper hook the Harrington rod in six cases, and in ie cases displacement of the lower hook on neural arch (Figure 3) Both Pigott (1976) Bjerkreim (1976) *have reported a con-* rable loss of correction in cases where the ing wire is omitted The locking wire is used routinely

n all the patients a cloudy structure of anized mature bone, corresponding to the e chips, was seen at the 1-year check-up, no cases of pseudarthrosis were detected ordinary X-rays There have not been is of deep infection or of deep thrombosis. final improvement of 33 per cent of the ial curve corresponds with results ained by others (Nordwall 1973, Pigott 76 and Bjerkreim 1976) and this result is ained with few actual complications. All ients had a visible, but acceptable rib np after the operation. Only a modest otation, measured according to Nash & e (1969), took place at the operation.

f one compares the results of today, using Harrington instrumentation technique, h earlier operative treatment (Buus & gaard 1977), a considerable improvement cerning maintenance of curve correction is n.

After conclusion of this material the post- rative period of bed rest has been rtened to 2–3 weeks, and this has not changed the results Using Harrington's in strumentation technique, with posterior fusion and a Milwaukee brace for 1 year post-operatively, a good correction of severe scoliotic curves may be obtained, without major complications It is, however, desirable for scoliosis patients to be operatively treated before the curve becomes too severe (about 50–60°)

REFERENCES

Bjerkreim, I (1976) Operative treatment of scoliosis with Harrington instrumentation technique. *Acta orthop scand* 47, 397–403

Buus, E & Pilgaard, S (1977) Spinal fusion (Abstract) *Acta orthop scand* 48, 334

Cobb, J R. (1960) The problem of the primary curve *J Bone Jt Surg* 42-A, 1413–1426

Dickson, J H & Harrington P R (1973) The evolution of Harrington instrumentation technique in scoliosis *J Bone Jt Surg* 55-A, 993–1002

Goldstein, L A (1969) Treatment of idiopathic scoliosis by Harrington instrumentation and [illegible] bone grafts. [illegible] *J* [illegible]

James, J I P (1976) *Scoliosis*, 2nd ed. p 273 Churchill and Livingstone, Edinburgh, London & New York.

Leider, L L., Moe, J H & Winter, R. B (1973) Early ambulation after the surgical treatment of idiopathic scoliosis *J Bone Jt Surg* 55 A, 1003–1015

Nachemson, A. (1976) Terapeutiska framsteg inom skoliosområdet *Svenska Lak-Tidn* 73, 953–961

[illegible] vertebral rotation. *J Bone Jt Surg* [illegible], 223–229

Nordwall, A. (1973) Studies in idiopathic scoliosis. *Acta orthop scand*, Suppl. 150

Pigott, H (1976) Treatment of scoliosis by posterior fusion, Harrington instrumentation and early walking *J Bone Jt Surg* 58-B, 58–63

Schultz, A. B & Hirsch C (1973) Mechanical analysis of Harrington rod correction of idiopathic scoliosis. *J Bone Jt Surg* 55 A, 983–992.

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engaging different nervous structures, from peripheral nerves up to central structures in the brain (Robin 1975) Another symptom of these diseases may be a disturbed equilibrium function.

Posture and postural control

The equilibrium in upright posture is dynamically controlled, and a slight postural sway is a normal phenomenon The postural sway occurs both in the sagittal and the lateral plane and represents a complex reflex process, involving acquisition and processing of sensory information as well as execution of motor commands. The input information originates from proprioceptors in the muscles, joints, ligaments and tendons, and from the vestibular and the visual apparatuses Postural reflex activity can be initiated in the proprioceptive system at the spinal level Much of the input concerning postural equilibrium is co-ordinated into proper motor commands at supraspinal centres through a continuous integration of impulses from the different receptor systems The vestibular nuclei, the reticular formation, and the cerebellum form a functional group at the brain stem level which is of vital importance for postural equilibrium control More demanding sensory processing involves the basal ganglia and also the cerebral cortex (Frederickson et al 1966 Guyton 1976 Martin 1967, Nashner 1970, Roberts 1967)

It has often been shown that the complex regulatory process of postural equilibrium can be disturbed by various neurological disorders involving different levels in the central nervous system.

Techniques for studying postural sway

A number of methods for studying the act of standing have been described in the literature, but none is free from criticism In principal, any method or combination of methods that records information pertaining to the control process and the performance can be used. For obvious reasons, the external recording sites must usually be selected and the methods narrowed down to kinesiological techniques, i e, methods of studying movements by means of film photography electromyography, and measurements with accelerometers and force transducers, etc These methods have recently been reviewed by Grieve et al. (1975). In stabilometry a force platform of varying design is the most frequent recording instrument (Terekhov 1976) The force platform responds to the projection on the horizontal base plane of the movements of the body's centre of gravity which are inevitably present while standing For evaluation, the lateral and sagittal sway amplitudes and centre and size of the sway area (Njiokiktjien & de Rijke 1972) and other statistical signal characteristics, e g, power spectra, are often estimated (Bensel & Dzendolet 1968, Cernacek et al 1973, Eklund & Löfstedt 1970, Leroux et al. 1973, Scott & Dzendolet 1972). Other measures, subjective as well as objective, are also frequently used

The use of force platforms in studies of postural sway has several advantages. The test procedure is simple, and very easy to explain to the subjects. It can readily be adapted to give prominence to specific aspects of the postural control mechanisms (Tourtelotte et al 1965), and the recorded signals can be evaluated quantitatively by means of electronic signal processing equipment. The mechanical analysis of the results can be involved, however, because of the large number of degrees of freedom of movements of the body (Murray et al. 1967) Since the force platform responds to movement characteristics closely related to those affecting the physiological receptor systems, the test is well suited to an analysis of postural control in terms of control theory and mathematical models (McRuher et al 1968, Nashner 1970 Paltser & Agashyan 1974).

Aim of the present study

The aim of the present investigation was to study quantitatively, by means of

stabilometry, the postural equilibrium in a group of patients with adolescent idiopathic scoliosis and to compare these results with those obtained in a control group In addition it was of interest to obtain a qualitative measure of the function in the afferent regulatory systems controlling upright posture

METHODS

Experimental design

The degree of difficulty of standing in the different tests was varied by having the subjects eyes open or closed and by having a stable or compliant base support Four tests were used in the recordings in the following sequence

1 Standing on a stable base support with eyes open
2 Standing on a stable base support with eyes closed
3 Standing on a compliant base support with eyes open
4 Standing on a compliant base support with eyes closed

The stable base support was identical with the horizontal and rigid surface of the platform and the compliant base support was accomplished by laying a 10 cm thick piece of foam rubber on the platform

Experimental procedure

The subjects were allowed to become acquainted with the test procedure All tests were conducted with the subject naked except for underpants The positioning of the feet on the platform was always the same with the heels together and the feet at an angle of 30 degrees. In Tests 3 and 4 the piece of foam rubber was fitted to the platform and the subject was assisted in positioning his feet accurately For the test conducted with his eyes open, the subject was instructed to fix his gaze upon a 10 × 10 cm reference square placed at a distance of 5 m in front of the platform and adjusted to eye level. The room was artificially illuminated The subject was also instructed to stand relaxed with equal weight on both feet and with his arms hanging freely along the sides of his trunk. The recording of each test lasted 2 minutes whereupon the subject was asked to sit down on a chair and relax for a period of about 2 minutes before the next test

As a special study the effects of brace treatment on postural equilibrium were investigated The patients participating in this part of the study were tested as follows

1 As all other patients before any treatment
2 In a well fitted brace about 1 week after Test 1
3 At the same time as Test 2 but without the brace when the brace had been off for 10 minutes
4 At a routine follow up about 6 weeks after the brace treatment started

Recording equipment

The postural sway was recorded by means of a force platform provided with a unit for transducer excitation and signal processing and display The equipment was especially made for stabilometry by L'Electronique Appliquée Montrouge, France (Baron 1964 Barigant et al 1973). The platform measured 44 × 44 × 17 cm and it had a foot guide directing the foot angle (30 degrees) and enabling centring of the subject in the forward-backward direction Force transducers were placed in the middle of the sides of the platform. Each transducer consisted of a dynamometer ring and a differential transformer sensing the compression of the ring caused by a vertical force component The transducer signals were processed electronically to yield two signals, representing sway components in the forward-backward direction and in the left right direction, respectively These signals were connected to an FM tape recorder (Racal Thermionic, Store 4) for subsequent analysis, and to an XY-recorder (Houston Instrument Omnigraph EHR 95 TV) for monitoring purposes during the recordings The frequency range of the signal channels was from 0 to 10 Hz

Defining a co-ordinate system with its origin at the geometrical centre of the platform, its positive y axis forwards, and its positive x axis to the right (Figure 1) calibration of the platform yielded the y sensitivity (torque about the x axis) 0.102 V/Nm (0 0100 V/kpcm) and the x sensitivity (torque about the y axis) 0 123 V/Nm (0 0121 V/kpcm) The sensitivities were orthogonal and neither of them was affected by the position of the foot guide The offset and the hysteresis of the platform had a negligible effect on the output signals. The non linearity was less than 5 per cent in the y-direction and less than 7 per cent in the x-direction

Evaluation procedure

The signals recorded on tape were played back at a speed four times greater than during

:ding The signals were fed to second-order, erworth low-pass filters (Hewlett-Packard, A) the cut-off frequencies of which were lz (corresponding to the real time frequency Hz). The outputs of the filters were connected ie analogue-to-digital converters of a computer P 15). The sampling frequency for each nel was 80 Hz (real time frequency 20 Hz) r digitalization, the data sequences were layed on an oscilloscope screen and checked artifacts and equipment faults, and further ded into separate files. In this procedure the ording artifacts between the sequences – sed by starting and stopping the tape recorder vere used as markers. The files were named ording to subjects and recording conditions. In il, 770 files were recorded, containing about 12 lion data words.

The recorded voltages were converted to uivalent length-co-ordinates through division by overall calibration factor and the weight of the oject. These co-ordinates indicate the locus of action point – on the platform surface – of a tical supportive force having a magnitude equal the weight of the subject. When the acceleran forces are small compared with the vitational forces, this point indicates the protion of the centre of gravity of the body on the y plane Considering the time series of the length-ordinates thus estimated as realizations of an godic bivariate stochastic process, statistical gnal parameters characterizing the sway were lculated mean values and root mean-square lues (rms values) The mean values x_m and y_m id cate the position of the centre of the sway id the rms values s_x and s_y indicate the sway mplitude in the lateral plane and in the sagittal lane, respectively In addition assuming ormality, parameters of the confidence ellipse of ne joint probability density function of the sway t the level $e^{-\frac{1}{2}}$ of maximum were calculated Figure 1) At this level the degree of confidence is 93 per cent The area A of the ellipse is a statistical measure of the total sway amplitude, which takes a possible correlation between the x- and y-components into account The correlation also infl [illegible]

[illegible]

adjacent samples (Persson 1974), only every third sample was used in all these calculations. All parameters estimated were treated statistically mean values, standard errors of the means, and 95 per cent confidence intervals were calculated for groups of subjects – the subjects being assigned to one or more groups according to clinical characteristics. To compare the inter individual

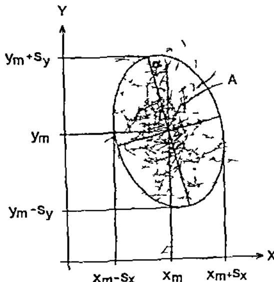


Figure 1 Statistical description of postural sway in the x-y plane The confidence ellipse of area A has its centre in (x_m, y_m) The tangents parallel to the coordinate axes yield the standard deviations of the marginal distributions which are equal to the rms values of the sway components s_x and s_y in the lateral and sagittal directions, respectively The scale of the locus trace has been reduced by a factor of two to increase clarity

variability with the intra individual variability, the estimated parameters were normalized to their corresponding values in the first test situation. This value was subtracted from the means of co-ordinate and angle values, yielding standard value zero and it was used as divisor with the sway amplitudes, yielding standard value one

Using the estimated parameters to characterize the various groups, differences between the groups were investigated by means of Student's *t*-test – assuming equal variances – of the 5 per cent level of significance

MATERIAL

The study comprised 57 patients with adolescent idiopathic scoliosis (AIS) referred to the Department of Orthopaedic Surgery I, Sahlgren Hospital during the years 1975 and 1976 The controls were randomly recruited from a material of healthy children previously described by Petersén & Eeg-Olofsson (1971) The reason for this recruitment was that the history and the somatic-neurological status in these children had been carefully studied previously The controls were of

similar age and had the same sex ratio as the scoliotics (Table 1) The 48 patients with single major structural curvatures were subgrouped with regard to the magnitude and convexity of the curvature (Table 2)

Nine scoliotics with double-primary curvatures formed a separate group in this study These patients had two curvatures of major degree, both with structural changes The classification of the patients followed the definitions laid down by the Scoliosis Research Society (1976) The scoliotic patients were classified with regard to whether the deformity required treatment or not All of the patients with double-primary curvatures required treatment As a rule, the indication for treatment (brace or surgery) was a curvature of more than 20 degrees (Cobb 1948) in a patient still skeletally immature Two patients, who required a brace and both had a curvature of 17 degrees were the only exceptions to this rule Eight of the patients with a single major curvature required surgery The two different subgroups requiring treatment were analysed together and the patients were investigated before any treatment

Five of the patients with single curvatures and three of the patients among the double-primary scoliotics participated in the special study of brace effects

The past history was extensively penetrated in all the subjects and they were given a thorough

Table 1 Material

	Scoliotics (single curves)	Controls
Number	48	32
Mean age (years ± SD)	13 4 ± 1 7	13 3 ± 2.1
Age range	10–16	10–16
Sex ratio ♂/♀	8/40 (20 %♂)	5/27 (19 %♂)

Table 2 Grouping of the scoliotic patients with regard to magnitude and convexity

	Patients placed under observation	Patients requiring treatment	Total
Right convex single curve	8	19	27
Left convex single curve	10	11	21
Double primary curve		9	9
Total	18	39	57

physical examination with emphasis on neurological status, according to a s[…] schedule None of the patients was taking [...] and all abstained from tobacco and coffee o[n the] day of the investigation.

RESULTS

None of the children presented [...] neurological sign of pathological importa[nce] in the clinical examination

Graphical comparison of the lateral [and] sagittal sway amplitudes, s_x and s_y, and of [the] total sway A are presented in Figures 2 [and] 3 * A summary of the statistical analyses [is] shown in Table 3

The average position x_m of the lateral [...] is to the right of the centre of the suppo[rt] area for the controls as well as in right [and] left scoliotics In the right convex patients th[e] shift is significantly more pronounced th[an in] the controls. The left convex patients al[so] have a shift to the right, although they do n[ot] differ significantly from the controls. The d[is]placement to the right for all these groups [is] preserved in Test 2 Patients placed under observation have a more pronounced d[is]placement x_m than patients requiring treatment, in both the right and left conve[x] group This result is statistically signi[ficant] ($P < 0.05$) for the left convex patients in Te[st] 2

The sway in the sagittal plane s_y is more pronounced in the scoliotic patients compared with the controls in all of the tests. A common feature is the almost consistently increased degree of significance for the la[ter]al sway s_y compared with the sagittal sway s_y The significant difference in the sagittal sway – as well as in the other parameters analysed – between scoliotic patients and controls is most conspicuous in the tests from which visual sensory information is excluded. The patients placed under observation were found to have the most pronounced differences in sagittal sway compared with the controls [...]

* Detailed results in table form can be obtained by applying to Tage Sahlstrand

*Table 3 Summary of statistical analyses. The results of the tests are indicated with *, **, *** and **** [illegible] respectively*

	Test 1 Quiet stance eyes open						Test 2 Quiet stance eyes closed							Test 3 Compliant base eyes open				Test 4 Compliant base eyes closed			
	s_m	s_y	s_x	s_y/s_x	A	α	$\bar{x}_n$	$\bar{x}_m-\bar{x}_n$	s_y	s_x	s_y/s_x	A	α	s_y	s_x	s_y/s_x	A	s_y	s_x	s_y/s_x	A
Controls/single curves					*				***	****		****						***	****	*	****
[illegible]			*						****	****		****		*	*		*	***	****	***	****
[illegible]	****	*					**		****	****		****		*	*		*	***	****		****
[illegible]			*	*		*	*		*	****		****						*	****		***
Controls/patients [illegible]									*	**		**						*	***		**
Controls/patients [illegible] right convex										*		****							*		
Controls/patients requiring treatment left convex						*			*	*		*						*	***		***
Controls/right convex scoliotics	**						*		***	****		***						*	***		***
Controls/left convex scoliotics			*			**			*	****		****						***	****	*	***
Controls/double primary curves										**		**							*		
Patients placed under observation/requiring treatment										*		*							*		
Patients placed under observation/requiring treatment right convex																			*		
Patients placed under observation/requiring treatment left convex							*														
Right convex/left convex scoliotics						*															
Right convex/left convex scoliotics patients placed under observation				*		*															
Right convex/left convex scoliotics patients requiring treatment																					
Single curves/double primary curves																					

Test 3 The right convex patients requiring treatment, on the other hand did not show any significant differences in sagittal sway compared with the controls in any of the test situations.

The scoliotics also had a clear increase in the lateral sway s_x compared with the controls. Another interesting feature is the very marked increase in lateral sway s_x in the tests from which visual information is excluded (Tests 2 and 4) As previously stated, when the scoliotics are compared with the controls the significance is more pronounced in these test situations for the lateral sway than for the sagittal sway Significant differences under these conditions were also found for the right convex patients requiring treatment. In the lateral sway the difference between the patients placed under observation and the patients requiring treatment became most obvious. The patients placed under observation had a significantly ($P<0.05$) increased postural sway in Tests 2 and 4 compared with the patients requiring treatment and in Test 4 the right convex patients of these two groups also differed significantly ($P<0.05$)

The total sway area A is related to the sagittal and lateral sway Analysis of this parameter also showed results similar to the other ones. One exception is the comparison between the total group of scoliotics and controls in Test 1 Even in this "easy" test situation a significantly increased sway could be detected in the scoliotic group ($P<0.05$)

A decreased s_y/s_x quotient compared with the controls, i.e a lateralization of the sway was noted in Test 4 This finding was valid for the total scoliotic group ($P<0.05$) as well as for the patients placed under observation ($P<0.05$) and left convex patients ($P<0.05$) In comparisons between the scoliotic groups the only significant finding was that left convex patients placed under observation had a lower quotient compared with right convex patients with the same magnitude of curvature ($P<0.05$).

The average direction of the sway showed significant differences between the groups only in Test 1 The angle α had a negative value in left convex scoliotics. This value was significantly different from that obtained in the controls ($P<0.01$) The difference persisted when the left convex patients were subgrouped. The right convex patients and the controls had the same value of α When these patients were subgrouped however the result is obviously a synthesis of a pronounced positive value for the patients placed under observation and a slight negative value for the patients requiring treatment. Statistical comparisons between the scoliotic groups revealed

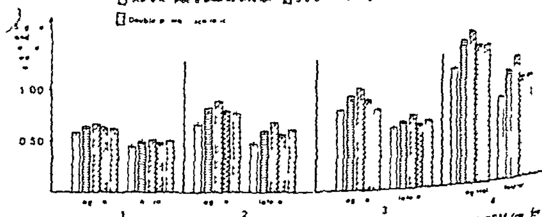
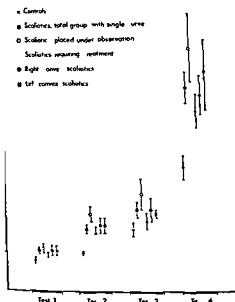


Figure 2 Graphical comparison of sagittal sway s_y and lateral sway s_x. Mean and SEM (cm) for each of the four tests



ure 3 Graphical comparison of total sway A in and SEM (cm²) for each of the four tests

ifference between the right and the left vex patients as total groups as well as ween the patients placed under observation. For the double-primary scoliotics a ificantly increased lateral sway was noted Tests 2 and 4 The total sway was also reased in Test 2 No significant difference s noted in any other test or parameter

When investigating the effect of wearing a ice using the total sway area A as a terion, there were no statistically signifi- nt differences either for the test in a well- ed brace at the start of the treatment or the test after 6 weeks of treatment

ISCUSSION

laintenance of upright posture is a complex echanism and investigation and clinical ssessment are rather subjective and non- eproducible Factors such as amplitude and tero-pulsion are hardly registered by the linician (Njiokiktjien & de Rijke 1972) mall and perhaps subclinical disturbances may not be detected unless a suitable method and investigation design are available

In designing an equilibrium investigation it is necessary to include tests sufficiently difficult to challenge the nervous system and its neural processing of signals from different afferent sources (Stribley et al 1974) To obtain information about how these different reflex activities are functioning and to obtain a measure of the relative importance of the participating afferent systems, specific ex perimental situations can be designed. In these the afferent information can be enhanced, weakened or excluded (Eklund & Lofstedt 1970, Gantchev et al 1972 Kapteyn 1972, Le & Lishman 1975 Murray et al 1975, Stribley et al 1974) Visual input is considered important in the maintenance of postural equilibrium (Gantchev et al 1972, Guyton 1976) Lee & Lishman (1975) even postulated that vision can provide more sensitive information than the proprioceptive system Nashner (1970) found that information from the visual system can be more accurate than that from the vestibular system with a lower threshold for detection of spatial changes of the body in comparison with vestibular sensors. Although visual signals seem to dominate they co-ordinate with labyrinthine receptors in postural control and do not replace them (Nashner 1970) An indirect measure of the importance of visual information for postural control may be obtained by noting changes in postural sway when vision is excluded and included in the test situation.

The characteristics of the base support determine to what extent the vestibular system is involved. With an increasing unevenness in the ground the labyrinthine activity becomes relatively more important (Lee & Lishman 1975, Martin 1967, Njiokiktjien 1971, Stahle, personal communication 1977).

The importance of the proprioceptive system increases when visual information is excluded (Gantchev et al. 1972, Roberts 1967) Most authors agree that proprioception dominates over the vestibular system as long

as the individual is standing on a stable and firm surface (Martin 1967, Njiokiktjien & de Rijke 1972) The orientation of the body is accurately reflected by the angles of the ankles and from mechanoreceptors that signal the pressure between the feet and the base support Under these conditions the level of processing can to a greater extent be dealt with at the spinal level in the central nervous system through spinal reflexes (Nashner 1970) However, when the individual is standing on a compliant or unstable surface the proprioceptive information becomes unreliable (Lee & Lishman 1975, Nashner 1970) For maintenance of postural equilibrium under these conditions supraspinal processing is needed to a greater extent In this mechanism vestibular and visual sensors are involved, integrated mainly at the brain stem level with upwards radiating proprioceptive impulses.

Thus, in the present investigation it may be assumed that the afferent systems have been tested schematically as follows

Test 1 Proprioception, mainly at spinal levels, the visual system and to a slight extent the vestibular system

Test 2 Proprioception, mainly at spinal levels, and the vestibular system possibly more than in Test 1

Test 3 Proprioception, mainly at supraspinal levels, the visual and the vestibular systems

Test 4 Proprioception, mainly at supraspinal levels, and the vestibular system to a greater extent than in the other tests

The most striking result of this investigation is the increased postural sway in the scoliotic patients compared with the children with straight spines This is most conspicuous in the two tests in which the individuals had their vision excluded and had to rely on the proprioceptive and vestibular functions

With visual input the postural equilibrium is dramatically improved Whether a stable base support is used or not, the visual information seems important for the scoliotic patients for improving their postural stability This finding contradicts a hypothesis that the decreased postural control in the scoliotic group is caused by any important disturbances in the visual system

There are differences of opinion in the literature about the role of the vestibular system in the test situations used here (Kapteyn 1972) There is general agreement, however, that the vestibular system is involved to some extent in all the tests in the present investigation and that it must be most important in Test 4, i.e when the subject is standing on a compliant surface with his eyes closed The statistical analysis did not reveal any difference between the results of Test 2 and Test 4 All the different scoliotic groups had a significantly increased sway, totally as well as in the lateral and sagittal direction Of course the importance of a more significant contributory vestibular factor in Test 4 may be missed when there are already such clear differences in Test 2 Apart from a disturbed proprioceptive process at the spinal as well as the supraspinal levels, a defective vestibular sensoring cannot be ruled out, especially as the scoliotic patients had a lower quotient between the sagittal and lateral sway and they demonstrate the lateralized pattern of the postural sway This phenomenon has earlier been recognized as a possible sign of vestibular disturbance (Njiokiktjien & de Rijke 1972)

The differences between the scoliotic patients and the control children cannot be explained by the composition of the material The age and sex pattern as well as constitutional factors such as weight and height are about the same in the two groups The investigation was carried out under the same conditions for the patients and the controls The only exception was that the patients requiring treatment were participating in the study as inpatients. If this circumstance had constituted a "stress" factor influencing the result, these children would have been expected to have a greater postural sway than the patients placed under observation. But the

the contrary, the patients placed under observation participating as outpatients had a poorer equilibrium performance compared with the patients requiring treatment

This leads us to the question of whether these findings might be of aetiological importance or whether the disequilibrium reflects a phenomenon that is secondary to the deformed spine If a dysfunction in the postural equilibrium is secondary to the idiopathic curvature, it seems reasonable to assume that a patient with a more severe curvature will have more dysfunction However, this study has shown a clear-cut y in all the analysed tests for the patients requiring treatment to have a decreased postural sway compared with the patients placed under observation, i e, the children with small curvatures. The tendency becomes statistically significant in Test 2 and Test 4 for the lateral sway and in Test 2 also in the total sway The superior equilibrium performance of the patients given treatment was also evident when these two subgroups were compared with the controls (Table 3) This result is difficult to interpret It does not, however, support any theory of a postural dysfunction as an effect of a crooked spine

With a feed back theory as background, the double primary curvatures are interesting to study Like the patients with single structural curvatures, they turn out to have a significantly increased postural sway compared with the controls in Test 2 and Test 4 and they do not differ from these in the between-group comparison among the scoliotics.

It might be possible that the patients placed under observation and those requiring treatment have been studied in different situations at the time of the development of the disease The cases placed under observa tion might have been investigated in an earlier and perhaps more sensitive phase of the disease This possibility has been considered and a separate analysis reveals that the deformity had been recognized for the same length of time in the two groups. A brace is considered to stabilize the spine and we know from radiograms that it diminishes the curvature However, the special study of the brace effect on postural equilibrium did not seem to support the theory that the disturbed postural equilibrium in these patients was caused by the scoliosis. In the tested patients improvement and aggravation were about equally frequent It seems reasonable to assume that the existence of an active feed back mechanism of any importance would have resulted in a more clear cut tendency towards improvement of postural equilibrium when the patients received their braces.

In summing up the discussion of what is cause and what is effect, we must begin by stating, like so many investigators who have approached idiopathic scoliosis from an aetiological point of view before us, that once a curvature is established it is difficult to say what came first the different signs or symptoms or the deformity? However, the comparison between the findings in patients with small and more severe curvatures, the results in the double-primary group and the findings in the brace study do not support the theory of the crooked spine as the cause of the disequilibrium in the scoliotic patients On the other hand, the observations in these patients are not direct evidence that the significant differences in postural equilibrium between the scoliotics and the controls are of aetiological importance Elucidation of this point requires further study of the outcome for the patients placed under observation in this study This measure will not be enough, since our material is too small to clearly elucidate this issue adequately A longitudinal study in a larger group of patients with smaller idiopathic curvatures, still not requiring treatment, is needed to study this issue more thoroughly

On the whole there are no significant differences in angle values between right and left convex patients except in Test 1 The angle α is a measure of the average direction of sway, and this parameter may reflect such phenomena as rotation and laterotorsion of

the body This assumption is supported by findings in this comparison, bearing in mind that in the characteristics of the deformity in idiopathic scoliosis rotation is included When starting from the assumption that the angle α might be a measure of rotation and laterotorsion, the left convex patients seem to have a more pronounced feature of such phenomena than the right convex patients and they also seem to react to a great extent regarding such phenomena when closing their eyes A different reaction pattern is also found in the s_y/s_x-quotient when left and right convex patients are compared When the patients are subgrouped according to the magnitude of the curvature, the left convex scoliotics also turn out to have a different pattern in the quotient between sagittal and lateral sway, with a clear lateralization of the sway compared with the right convex patients It is known (Njiokiktjien 1971) that the majority of people have their projection of centre of gravity to the right, as had our controls and right convex scoliotics An unexpected and somewhat surprising finding is that the left convex patients also had their centre of sway in the lateral plane directed to the right

Summarizing the comparison between the right and left convex groups, the left convex patients had quantitatively more pronounced reactions than the right convex patients

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REFERENCES

Barigant P, Merlet P Orfait J & Tetar C (1973) New development of Ela Statokinesimeter *Agressologie* 13-C 69–74

Baron J B (1964) Présentation d un appareil pour mettre en évidence les déplacements du centre de gravité du corps dans le polygone d sustentation *Arch Mal. prof* 25, 41 4?

Bensel C K & Dzendolet, E (1968) P... spectral density analysis of the standing ... of males *Perception & Psychophysics* ... 285–288

Cernacek J, Jagr, J, Harman B & Vydrzel ... (1973) Stabilographic findings in ... vestibular disturbances. *Agressologie* 14... 21–26

Cobb, J R (1948) Outline for the study of scolio... Instructional Course Lectures, The Americ... Academy of Orthopaedic Surgeons, ... 261–275

Eklund G & Lofstedt L (1970) Bio-mechan... analysis of balance *Med Engng* 5 333–33...

Fredricksson J M, Schwarz D & Kornhuber ... H (1966) Convergence and interaction ... vestibular and deep somatic afferents up... neurons in the vestibular nuclei of the cat. *Ac... oto-laryng (Stockh)* 61, 168–188.

Gantchev G-N, Draganova N & Dun... (1972) The role of visual information ... ocular movements for the maintenance of bo... equilibrium *Agressologie* 13 B 55–61

Grieve, D W, Miller D., Mitchelson, D. ... Smith P & Smith A J (1975) *Techniques f... the analysis of human movement* Lepus Boo... London

Guyton A (1976) *Organ physiology structure ... function of the nervous system* W B Saund... Co, London

Hoogmartens, M J & Basmajian J V (19... Postural tone in the deep spinal muscles ... idiopathic scoliosis patients and their sibli... *Electroenceph clin Neurophysiol.* 16, 93 11...

Kapteyn T S (1972) Data processing ... posturographic curves. *Agressologie* 13... 29–34

Kapteyn T S & De Wit G (1972) Post... graphy as an auxiliary in vestibular investiga... tion. *Acta oto-laryng (Stockh.)* 73, 104 111

Lee, D N & Lishman, J R. (1975) Visual pro... prioceptive control of stance *J Fre... Movement Stud* 1, 87–95

Leroux, J., Baron, J B, Bizzo, G., Bessine... J C, Gueguen C., Noto, R & Pacifici, M (19... Etude spectrale des déplacements ... antéropostérieurs et latéraux du centre de gravité de l'homme en orthost... *Agressologie* 14-C, 57–63

Manning, C W (1974) Muscle imbalance ... scoliosis, S I M P Research Monograph ... 180–183

Martin, J P (1967) *The basal ganglia and posture* pp 30–35 100–14... Pitman ... Publ., London

McRuher D T Magdaleno, R E & V... C

P (1968) A neuromuscular actuation system model IEEE Transactions on Man-Machine Systems, Vol MMS-9, 61–71

rray, M. P, Seireg A A. & Scholz, R C (1967) Center of gravity center of pressure, and supportive forces during human activities. *J appl Physiol* 23, 831–838

rray, M. P, Seireg A A & Sepic, S B (1975) Normal postural stability and steadiness Quantitative assessment. *J Bone Jt Surg* 57-A, 510–516.

shner, L. M. (1970) Sensory feed-back in human posture control. Thesis. Mass. Inst of Techn.

iokiltjien, Ch. (1971) Statokinesimetric recording of postural balance, physiological and pathological aspects. Thesis, Amsterdam

iokiltjien, Ch. & De Rijke, W (1972) The [illegible]

standing man. *Biofizika* 19, 932–937

ersson, J (1974) Comments on estimations and tests of EEG amplitude distributions. *Electroenceph. clin. Neurophysiol* 37, 309–313

tersén, I & Eeg-Olofsson, O (1971) The development of the electroencephalogram in normal children from the age of 1 through 15 years. Non paroxysmal activity *Neuropadiatrie* 3, 247–304

Roberts, T D M (1967) *Neurophysiology of postural mechanisms* Butterworth, London

Robin, G C (1975) *Scoliosis and neurological disease* A Halsted Press Book.

Scoliosis Research Society (1976) A glossary of scoliosis terms. Spine, Vol. 1, no 1, March 1976

Scott, D E & Dzendolet, E (1972) Quantification of sway in standing humans. *Agressologie* 13-B, 35–40

Stribley, R. F, Albers, J W, Tourtelotte, W W & Cockrell, J L. (1974) A quantitative study of stance in normal subjects. *Arch phys Med* 55, 74–80

Terekhov, Y (1976) Stabilometry and some aspects of its applications – a review *Bio-med Engng* 11, 12–15

Tourtelotte, W W, Haerer, A F, Simpson, J F, Vuzma, J W & Sikorski, J (1965) Quantitative clinical neurological testing *Ann. N Y Acad Sci* 122, 480–505

Yamada, K., Takaaki, I., Yamamoto, H, Nakagawa, Y, Tanaka, H & Tezuka, A. (1969) Equilibrium function in scoliosis and active corrective plaster jacket for the treatment *Tokushima J exp Med* 16, 1

Yamada, K & Yamamoto, H (1972) Equilibrium function in scoliosis and active corrective plaster jacket for treatment Amer Digest of Foreign Orthop Lit Third Quarter, pp 182–185

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A RATIONAL APPROACH TO THE USE OF EPIDURAL MEDICATION IN THE TREATMENT OF SCIATIC PAIN

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The results of a series of 120 epidural injections given as treat backache and sciatica using Methylprednisolone and local anae performed in the Gloucestershire area, are presented and compar other published results. Wide variations in the results of this treatm found and these may in part be explained on the basis of the severity of the histological changes known to occur in and aroun roots in cases of sciatica

The pathogenesis of sciatica in lumbar disc disease is d scu relation to its treatment by epidural injections of a long acting stero shown that the treatment is more successful in acute onset cases an that have epidurals within 6 months of the onset of symptoms an suggested that earlier epidurals are given in cases that do not resp the usual conservative measures Manipulation of the spine and stretch should not be carried out at the same time as the epidural, a procedures may adversely affect the results in some cases and certa to make them more difficult to assess.

Key words epidural, low back pain, Methylprednisolone, sciatica

Accepted 24 1 78

Sciatica is a common and disabling symptom and the cause of considerable economic loss both to the country and to the individual The Registrar General's figures show that absenteeism because of sciatica accounted for at least 7 million working days lost in the statistical year 1974–5

Epidural injections have been used in the treatment of this condition for over 70 years and epidural steroids for over 20 years Many authors have been very enthusiastic about this form of treatment, stating that it could cure many patients who had had prolonged and unsuccessful conservative treatment and it was instrumental in reducing the operation rate in lumbar disc disease Because of favourable reports, epidurals have bee creasingly used in the Gloucester Orthopaedic service The results obt correlated with other published suggest a more rational use of the treat which should in turn produce better re

MATERIAL

An unselected retrospective series of 120 p treated with epidural injections Gloucestershire area up to the end of 197 studied. There were 71 male and 47 f patients with ages ranging from 17 to 72 All the patients were suffering from "mech low-back pain and sciatica, other causes of pain were excluded by appropriate radi and haematological investigations.

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patients (37.5 per cent) were suffering from lumbar disc disease with no changes on normal plain radiographs, the diagnosis being based on the history and physical findings. Seventy-five patients (62.5 per cent) were noted to have degenerative changes in their lumbar spine with disc space narrowing. No patient had a spondylolisthesis.

Irrespective of the precise pathogenesis of their root irritation patients were categorized into the following groups on the basis of clinical presentation in order to assess the efficacy of treatment.

(a) Acute. Those with an acute onset, no previous history of sciatica and a total history of less than 6 months.

(b) Chronic. Those with a gradual onset of symptoms or a history of sciatica of more than 6 months and with a poor response to standard treatment.

(c) Recurrent. Those with a history of recurrent attacks of sciatica who had previously been completely cured by conservative treatment.

(d) "Radiculitis". There was a small group of patients who had originally had 'acute discs" whose straight leg raising and spinal mobility had been restored to normal by standard measures but who were left with typical sciatic pain.

METHOD

All patients received 80 mg Methylprednisolone in 20 ml of local anaesthetic (normally Lignocaine 1 per cent) by the lumbar route given in the lateral position with the affected side downwards.

Because this series is retrospective with patients under the care of different orthopaedic surgeons and injections given by several different anaesthetists there were some variations in the medication and method. In particular 70 patients (58 per cent) received in addition to their medication 25 mg of Hydrocortisone Acetate and an ampoule of Hyalase. Thirty-eight patients (32 per cent) had a manipulation of the spine and a sciatic stretch, carried out under general anaesthesia because of the presence of degenerative changes on plain radiograph of the lumbar spine and suspected root adhesions.

RESULTS

These are presented in Tables 1, 2 and 3. Follow-up was 1 year in all cases.

Success is defined as a very substantial improvement as regards pain, spinal mobility and straight leg raising, maintained for the period of follow-up. Failure is defined as either no improvement or an improvement such as to be of little material benefit to the patient. Those patients who gained only temporary or moderate relief, and had to continue with further treatment, were classed as failures.

Fifteen patients (13 per cent) who showed improvement followed by relapse had a second epidural and of these, 6 patients (40

Table 1. Results of epidural injection in the various categories

Category	Total number	Success %	Failure %
All cases	120	62	38
Chronic cases	65	44.5	55.5
Acute cases	31	81	19
Recurrent cases	16	81	19
"Residual radiculitis" cases	8	87.5	12.5
Postlaminectomy	7	28	72
Those with a history of the present attack of pain			
(i) less than 6 months (irrespective of total length of history)	65	80	20
(ii) more than 6 months	51	45	55

Increased success rates in "acute cases" and those with a history of pain of less than 6 months are statistically significant ($P<0.005$ and $P<0.001$ respectively on χ^2 test)

Table 2 Results of epidural injection related to X ray changes

Category	Total	Success %	Failure %
All patients	120	62	38
Those with X-ray changes	75	60	40
Those without X-ray changes	45	63	37

Table 3 Results of epidural injection related to associated administration of Hyalase (H) and Cortisone Acetate (CA), and manipulation under anaesthesia (MUA), and straight leg stretch (SLS).

Category	Number	Success %	Failure %
(a) All cases			
Total	120	62	38
Having H and CA	70	63	37
Not having H and CA	50	60	40
Having MUA and SLS	38	50	50
Not having MUA and SLS	82	67	32
(b) Chronic cases			
Total	65	44 5	55 5
Having H and CA	40	40	60
Not having H and CA	25	44	56
Having MUA and SLS	24	45	55
Not having MUA and SLS	41	44	56
(c) Acute Cases			
Total	31	81	19
Having H and CA	16	87	13
Not having H and CA	15	80	20
Having MUA and SLS	8	63	37
Not having MUA and SLS	23	87	13

There were insufficient "Recurrent" and "Residual radiculitis" cases to analyse separately
None of these differences in success rate is statistically significant

per cent) benefitted from the second injection and were classed as successes

It can be seen that there was a significant improvement in the success rate in patients having their epidural within 6 months of the onset of symptoms and those in the "Acute" category

The presence of degenerative changes on plain X-ray of the lumbar spine did not affect the results of epidural treatment (Table 2)

Variations in medication (Table 3) did not affect the results of the treatment but manipulation of the spine and sciatic stretch appeared to worsen the results in acute cases [This however just fails to be statistically significant ($P = 0\ 1630$).]

DISCUSSION

Widely differing results have been published by various authors using epidural treatment and it is evident that the medication used in the injections is only of secondary im

portance Various combinations of saline local anaesthetic and steroid injections have been used and the results differ significantly even in series using the same medication For example, using small volume steroid injections alone, the success rates are as follows

Dilke et al (1973)	65 per cent
Swerdlow & Sayle Creer (1970)	90 8 per cent
Winnie et al (1972)	100 per cent

It is therefore obvious that the precise pathogenesis of the sciatic pain is of importance in determining the results in individual cases and indeed a perusal of published work shows that very little attempt has been made to relate the results of treatment to the precise cause of the symptoms and this almost certainly accounts for the differences in the results

Despite these differences however, certain important facts emerge from the published series

1 The method is safe and indisputably more effective than standard conservative treatment as shown by a controlled trial (Dilke et al. 1973)

2 The route of injection (caudal or lumbar) is probably immaterial provided sufficient volume is used to distribute the epidural fluid to the desired level (Swerdlow & Sayle Creer 1970, Mathews & Yates 1969, Goebert et al 1961)

3 In chronic or long duration cases, a steroid preparation is required to improve the results (Swerdlow & Sayle Creer 1970, Beliveau 1971) and there appear to be advantages in the use of a long-acting steroid suspension such as Methylprednisolone (Fishman & Christy 1965, Burn & Langdon 1974, Seghal et al 1963)

4 The use of very large volumes of fluid appears to offer no advantages and may increase side effects, furthermore there is no evidence in the published work that a routine manipulation of the spine or a sciatic stretch improves the results.

5 Irrespective of the medication used the results are better in acute cases and in cases that have epidurals within 1 year of the onset of symptoms (Swerdlow & Sayle Creer 1970 Burn & Langdon 1970, Winnie et al. 1972 Warr et al 1972)

The precise cause of sciatic pain in individual patients may be difficult to diagnose but whether it is due to mechanical pressure from an acute disc prolapse or chronic osteophyte formation or chemical irritation from abnormal acid metabolites in degenerate discs (Lindhal 1966, Nachemson 1969) there is evidence that the common factor is inflammatory change of variable histological severity in and around the nerve root and perineurium (Lindhal & Rexted 1951)

As these histological changes appear to be progressive, it is reasonable to assume that the earlier a steroid epidural is given the more effective it will be, and that a nerve root infiltrated with chronic inflammatory cells will not be affected by a local steroid injection.

This concept is borne out by the observations from other series already mentioned and also by further observations from the present series, i e , 81–87 5 per cent success rate in "acute", "recurrent" and "residual radiculitis" cases, 84 per cent of these patients having epidurals within 6 months of the onset of symptoms. There is an 80 per cent success in all patients having epidurals within 6 months of the onset of symptoms There is only a 44 5 per cent success in "chronic" patients, 61 per cent of these having had symptoms for longer than 6 months when given their epidural

Conclusions

This series confirms the value of epidural injections in the treatment of sciatic pain It is felt that while there will always be some failures due to continued mechanical pressure on the nerve root, especially with degenerative osteophytosis, at least some of the failures are due to potentially reversible inflammatory changes in the nerve root being allowed to progress to the stage where they are beyond the help of a steroid injection

This is confirmed by a statistically significant increase in the success rate in acute cases and those who have an epidural within 6 months of the onset of symptoms It is therefore felt that

(a) Every effort should be made to prevent the occurrence of established root inflammatory change All patients with sciatica should therefore be assessed at an early stage by an orthopaedic surgeon Standard treatment may be instituted but if there is a poor response then an epidural should be given in every case, certainly before 6 months have elapsed

(b) A long-acting steroid should be used, probably in all cases and certainly in the longer duration cases

(c) A routine manipulation and sciatic stretch should not be carried out at the same time as the epidural as there is no evidence that it improves the results (the present series in fact suggests that it may worsen the results if carried out in acute cases although these figures just fail to be statistically significant) and it makes it difficult to assess the results of the epidural

ACKNOWLEDGEMENTS

I would like to thank Mr R Merryweather, Mr B D A Morris, Mr W M Lennox, Mr R A Davies and Mr R J Hart, whose cases I studied for their helpful advice and criticism and especially Mr Merryweather whose original suggestion resulted in the research for this article I would also like to acknowledge the anaesthetists working at Standish Hospital who carried out the majority of the injections and to thank Mr R S M Ling of the Princess Elizabeth Orthopaedic Hospital Exeter, for reading and criticizing the script and finally to thank Mr J Alexander of Southampton University for his help with the statistical analysis.

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REFERENCES

Beliveau, P (1971) A comparison between epidural anaesthesia with and without corticosteroid in the treatment of sciatica *Rheumat Phys Med* 11, 40–43

Burn J M B & Langdon L (1970) Lumbar epidural injection for the treatment of chronic sciatica *Rheumat Phys Med* 10, 368 [illegible]

Burn, J M B & Langdon, L (1974) Duration of action of Methylprednisolone A study in patients with lumbo-sciatic syndrome. *Amer J Phys Med* 53, 29–34

Dilke, T F W, Burry, H C & Grahame, R (1973) Extradural corticosteroid injection in the *management of lumbar nerve root compression Brit med J* 2, 635–637

Fishman, R A & Christy N P (1965) Fate of adrenal cortical steroids following intrathecal injection. *Neurology* 15, 1–6

Goebert, H W, Jallo S J, Gardner W J & Wasmuth, C. E (1961) Painful radiculopathy treated with epidural injections of Procaine and *Hydrocortisone Acetate Anaesthesia and Analgesia* 40, 130

Lindhal, O (1966) Hyperalgesia of the lumbar nerve roots in sciatica *Acta orthop scand* [illegible] 367

Lindhal O & Rexted B (1951) Histologic changes in spinal nerve roots of operated cases of sciatica *Acta orthop scand* 20, 215–[illegible]

Mathews, J A & Yates, D A H (19[illegible]) Reduction of lumbar disc prolapse by manipulation *Brit Med J* 3, 696.

Nachemson, A (1969) Intradiscal measurements of pH in patients with lumbar rhizopathies *Acta orthop scand* 40, 23–42.

Seghal, A D, Tweed D C, Gardner W J & Foote M K (1963) Laboratory studies after *intrathecal* corticosteroids. *Arch. Neurol* [illegible] 64–68

Swerdlow, M & Sayle Creer W (1970) A study of extradural medication in the relief of the lumbosciatic syndrome *Anaesthesia* 25, 3[illegible]

Warr, A C Wilkinson J A, Burn, J M B & Langdon L (1972) Chronic lumbo-sciatic syndrome treated by epidural injection and manipulation *Practitioner* 209, 53–59

Winnie, A P, Hartman, J T, Meyers H L, [illegible] (19[illegible]) Ramamurthy, S & Barangan, V Intradural and extradural corticosteroids for sciatica *Anaesthesia and Analgesia* 51, [illegible]

Acta orthop scand. 49 371–381 1978

HIP JOINT INSTABILITY AFTER THE NEONATAL PERIOD

Treatment of 20 Consecutive Cases

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A consecutive series of 20 children (21 hips) with idiopathic hip joint instability diagnosed after the neonatal period is presented The diagnosis was confirmed by hip joint arthrography In all the children, 1 5–21 months old at the time of diagnosis closed reduction could be achieved They were treated in plaster directly or after treatment of contractures in the adductor muscles of the hip joint

Stability was rapidly attained during plaster treatment

The results of the treatment in plaster were checked by a second arthrography in two thirds of the cases, and all cases have been clinically and radiologically evaluated 1–4 5 years after diagnosis. All of the children developed clinically stable hips and they walk normally In two hips signs of avascular necrosis of the femoral head were found and in three hips (two children) the skeletal development was markedly delayed In 81 per cent (17/21 hips) the prognosis was considered good it is uncertain in the remaining four hips.

The appropriate period of fixation in plaster related to the age of the child is discussed

Key words arthrography, hip instability late diagnosis plaster treatment

Accepted 6 ii 78

During the 1950 s, the diagnosis of and abduction treatment for hip joint instability in newborns was introduced into Sweden In 1963, 99 per cent of all newborns were included in the hip joint examination at the maternity clinics (Palmén 1970) The excellent results of diagnosis and treatment in an urban area (Malmö) have been presented by von Rosen (1970) and Fredensborg (1975) Practically all cases were diagnosed during the neonatal period On the other hand materials from Sweden as a whole (Palmén 1975), and from Uppsala University Hospital (Almby & Rehnberg 1977) have shown an unexpectedly high rate of cases diagnosed after the neonatal period

The value of arthrography in the diagnosis of hip joint instability discovered after the neonatal period has been demonstrated by Severin (1941) among others. Severin's material consisted mainly of children over 1 year of age As a result of the numerous and efficient Child Care Centres most cases not diagnosed during the neonatal period are now detected much earlier than before According to Palmén (personal communication 1977) most cases are now diagnosed before the age of 6 months.

Because the diagnosis and treatment of this group has been somewhat neglected in favour of the newborns the following study has been undertaken in order to elucidate the diagnosis

and treatment of hip joint instability after the neonatal period Arthrography has been used to analyse the changes in the joint Treatment has been guided by this examination

Definitions

Unstable hip joint Hip joint in which the femoral head is or can be moved out of the acetabulum partially or completely

Neonatal period The child's first month

PATIENTS

The series consists of 20 children, all girls They were born in the county of Uppsala and constitute all of the cases diagnosed after the neonatal period within the county from January 1972 to December 1975 The age at diagnosis was 1 5 to 21 months (Table 1)

All pregnancies followed a normal course, and delivery was normal in 17 cases. In two cases Caesarian section was undertaken and one case required vacuum extraction because of a drawnout delivery No breech deliveries were found All the children were born within the normal time except for two who were overdue by about 1 week Weight at birth varied from 2648 g to 4690 g (average 3606 g) One Rh immunized child showed a mild neonatal icterus. The others were all healthy

METHODS

Clinical diagnosis

Maternity Clinic All children were examined b consulting paediatrician with regard to hip j instability (positive Ortolani laxity) at leas o during the first week of life

Child Care Centres The children were exa by a paediatrician or a general practitioner a existing check ups, the first of which takes p at about 6 weeks of age and there are three to f further examinations during the first yea of l

Orthopaedic Clinic Consultation was requ by the physician at the Maternity Clinic or a Child Care Centre or by another physician children were examined with regard to per Ortolani provoked instability laxity lim abduction, asymmetrical thigh creases, a short and gait disturbances. After a radiological ex of the hip joints, the children were admitted to clinic for further treatment

The series has been divided into two age gr for this analysis

(1) Less than 12 months at diagnosis (16 g before walking)
(2) More than 12 months at diagnosis (4 g walking)

Radiological diagnosis

Radiological survey of the hip joints. In all ca three examinations are referred to

(1) Before any treatment

Table 1 Reason for orthopaedic examination ag ... leadin ... and the most ...

Reason for examination	No	Age		
1 Check up after exam at maternity clinic	3	1 5, 4		
2. Hip abnormality fou Care Centre	15			(3)
(a) routine exami		2, 3		
(b)		2, 3,		
3 Hip abnormality w for other illness		5		

(2) Within 5 weeks of completion of plaster treatment
(3) The most recent survey 1–4 5 years after diagnosis

At least two films were exposed on each of these occasions

(1) One a p view of the hip joints with the legs extended and rotated slightly inward
(2) One a.p view with the legs extended, abducted at least 45° and rotated maximally outward (Lauenstein's position)

At the first examination a test of stability was also introduced in which the legs were extended, rotated inward, and pressed axially

Arthrography Arthrograph [illegible]

dertaken, even in unilateral instability, as was done by Severin (1941) and [illegible]

[illegible] thereof 12 bilaterally Nine were examined within 2 weeks, the other four within 8 months of the completion of the plaster treatment

Standardized projections were used with the children always supine, with the legs symmetrically in different positions One film was always taken with the legs extended [illegible] presse[illegible] techn[illegible] paper

A total of 62 arthrographies have been done, all of acceptable quality The children were examined under general anaesthesia without complications The criteria suggested by Severin (1941) for a normal arthrogram have been used in assessing our material.

Treatment

In cases where there was little or no limitation in abduction, arthrography was done soon after admission In 11 hips with a limitation of abduction of more than 20°, traction treatment for 5–25 days was given before arthrography was done Radiological and clinical findings at arthrography, which was performed under gen[illegible] anaesthesia, decided further treatment. In 19 o[illegible] of 21 unstable hips reduction was successful the legs were fixed in a symmetrical hip [illegible] mostly while under the same anaesthesia In [illegible] oldest bilateral case, repeated attempts at reduct[illegible] were required before an acceptable position could b[illegible] attained If the limitation of abduction remai[illegible] after reduction, adductor tenotomy was carried ou[illegible] (Table 2).

Table 2 Treatment before plaster in 21 unstable hips (20 cases)

Age at diagnosis (months)	<12	>12
Traction/tenotomy	9	4
No treatment	7	1

In 17 out of 20 cases the position of treatment was 90° flexion and 70–80° abduction (so-called frog position) In the three remaining cases, maximal congruency in the joint was attained by 45° abduction and 20–30° inward rotation This position was used for the initial fixation Later [illegible]

Plaster casts were changed every 4 weeks. The length of treatment in plaster was, in the younger age group 13–27 weeks, in the older group 25–29 weeks.

After the period in plaster, treatment was continued with an abduction brace and the children have been followed for at least 1 year after diagnosis

RESULTS

Clinical findings at diagnosis

At the maternity clinic The paediatrician noted a positive Ortolani or laxity in four of the children during the first examination. Three of these were immediately referred for orthopaedic examination, and were at that time considered to have stable hip joints. No treatment was started, but continued check-ups at the orthopaedic clinic were considered necessary (Table 1 1) The fourth case was examined again by a paediatrician 2 and 5 days later, and was then considered to have stable hip joints. (This girl was later referred at the age of 4 months by the Child Care Centre with an abduction limitation, at which time a diagnosis of instability was made.)

At the Child Care Centres Abnormality in the hip was found in 15 cases, including the child mentioned above In general it was the limitation in abduction (sometimes combined with leg shortening) which led to a

Table 3 Clinical findings at diagnosis in 21 unstable hips (20 cases)

Age at diagnosis (months)	<12	>12	
	No	No	Total
Unstable hips	16	5	21
Findings			
Limited abduction	14	5	19
Leg shortening	10	4	14
Asymmetrical thigh crease	5	2	7
Positive Ortolani	5	0	5
Limp or other abnormal walk	—	5	5

referral, but other reasons were also given (Table 1 2)

In six of these cases the parents suspected an abnormal condition of the leg (Table 1 2) The four oldest of these children (8 17, 19, 21 months respectively) had been seen earlier at the Child Care Centre without abnormal findings

In two children hip abnormality was accidentally found during examination for another illness (Table 1 3)

At the orthopaedic clinic There was a family history of hip joint instability in three cases In 14 cases the left hip joint was affected, in 5 cases the right One girl had a bilateral instability (For other clinical findings, see Table 3)

The five hips with positive Ortolani in the younger age group could be reduced without prior treatment Two of these had no restriction in abduction, which however, was found in the other three and remained even after reduction All the other cases also had restricted abduction and could not be reduced

Radiological findings at diagnosis

Survey films of the hip joint showed a cranial displacement of the femur in all cases. In all cases but one there was a retarded ossification laterally in the iliac bone, which gave the acetabular roof a steeper appearance (Figure 1a). In the younger age group (16 cases), the epiphyseal nuclei were not visible bilaterally in seven they were of the same size in four, and smaller on the unstable side in five

In the older age group the epiphyseal nuclei were always smaller on the unstable side. In *the bilateral case, both epiphyses were* smaller than normal at that age

Arthrography In all cases, the femoral head either spontaneously or by force was displaced cranially and laterally Maximal cranial displacement appeared either with the leg abducted about 45° and rotated outward or rotated inward under axial pressure (Figures 2a 3a and 4) It was generally less than 5 mm in the younger age group and more than 5 mm in the older group

The shape of the femoral head differed from normal in 16 of the 21 unstable hips There was a variable degree of deformity from a slight flattening in the younger children (Figure 2a) to an obviously oval shape in the older children (Figures 3a and 4

The cranial part of the labrum acetabulare was always deformed (Figure 2) and sometimes difficult to define (Figures 3a and 4).

The joint capsule was widened in all cases (Figures 2 3a and 4).

In general a good reduction could be achieved (Figure 2b) In the oldest case with bilateral displacement no reduction could be attained in connection with the arthrography The reason for this was considered to be a residual limitation of abduction, and not an intracapsular obstruction.

Clinical findings after plaster treatment

At the completion of plaster treatment all the hips were clinically stable. No restriction in abduction remained.

In Figure 5 the length of plaster treatment in this series is shown. The length of [illegible] treatment has differed greatly in the children aged under 6 months. One girl diagnosed at [illegible] months of age was treated in plaster for [illegible] weeks, the shortest period of treatment in the series. Two months later a slight [illegible]



Figure 1a 5 month old girl Before treatment. Arrows (↑) indicate axial pressure on the legs Left hip joint unstable with retarded skeletal development of the acetabulum laterally in the iliac bone Femoral head bone nuclei missing bilaterally



Figure 1b Same girl 9 months old After 14 weeks treatment in plaster for left hip instability No displacement The bone nucleus in the femoral head is small An irregular ossification margin is visible in the iliac bone



Figure 1c. Same girl 22 months old No displacement Bone nucleus in the left femoral head still smaller than the
development of the acetabulum normal.

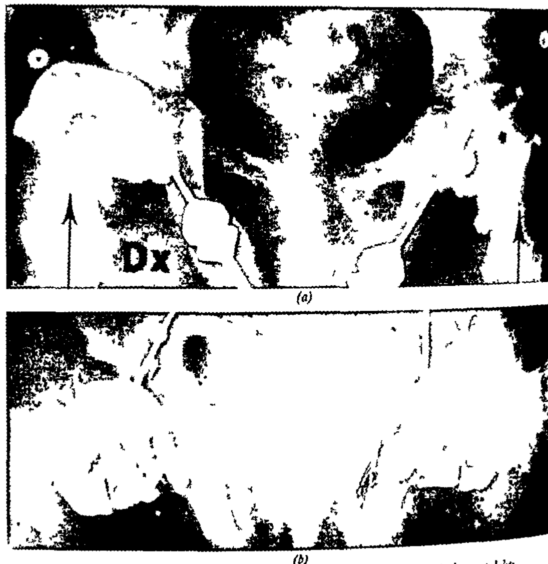


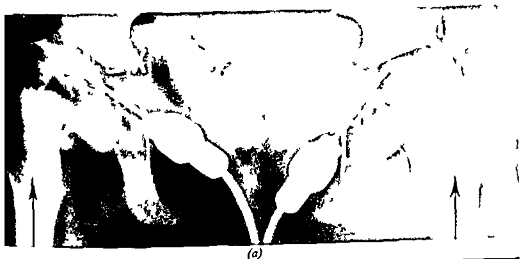
Figure 2 Bilateral arthrography 4 month old girl after 2 weeks traction Right hip instability
(a) Arrows (↑) indicate axial pressure on the legs Max displacement Right femoral head [illegible] deformed cranially and medially Labrum acetabulare pushed cranially Wide joint (Air [illegible] joints accidentally Metal indicators for stereoradiographic assessment)
(b) An excellent reduction in frog position

during outward rotation could be demonstrated Treatment in an abduction brace was therefore extended to 8 months, following which arthrography showed a normal joint Continued observation over a period of 16 months has shown the hip to remain normal.

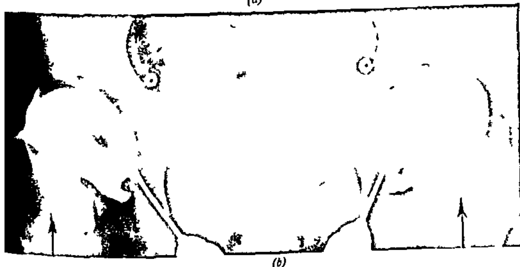
The children have been followed for 1–4 5 years, 11 of them for at least 3 years after diagnosis. All the hips were clinically stable at the most recent check-up with a normal range of movement No subjective problems [illegible] been reported No limp has been observed

Radiological findings after plaster [illegible]

Arthrography showed no cranial [illegible] of the femoral head, even [illegible] pressure on the legs, in 10 out of 14 [illegible] hips. In four hips (the three older [illegible] femoral head could be displaced [illegible] maximum of 5 mm.



(a)



(b)

[illegible] d in its [illegible]

(b) Same girl 2 years old After treatment in plaster for 26 weeks Arrows ( ) as in [illegible] *Stable No femoral head deformity Labrum acetabulare in normal position (Metal indicators as in Figure 2)*

Widening of the capsule remained in 10 hips, but was less extensive than at the first arthrography In these hips the femoral head could be displaced laterally 1–5 mm but only in abduction and outward rotation

In four hips, the femoral head was normal in shape at this examination as at the arthrography before treatment In the other 10 the deformation of the femoral head was less pronounced (Figure 3b) but it could still be seen in eight hips.

The labrum acetabulare had a normal position in 10 hips. In the three oldest cases, it was still deformed

On survey films at the end of plaster treatment, retarded skeletal devel pment was still seen in the previously unstable h p joint This was most marked in the cases which were diagnosed late In one case no femoral head nuclei could be found bilaterally at the age of 8 months. In all the other cases, the



Figure 4 Bilateral arthrography The oldest girl, 2 [illegible] *stability Arrows (↑) indicate axial pressure on the head clearly deformed bilaterally Labrum acetabu*[illegible] *joints*

epiphyseal nucleus was clearly smaller on the previously unstable side (Figure 1b) In one case this was combined with an irregular and flattened epiphyseal nucleus as well as an irregularity in the metaphyseal bone Only in one case had the acetabulum become completely normal In the others, the previously demonstrated lateral defect was completely or partially filled, instead, the ossification margin in the iliac bone was more or less irregular (Figure 1b)

During the first year after plaster treatment

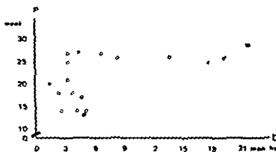


Figure 5 Age at diagnosis (D) in relation to the length of treatment in plaster (P)
Symbols ○—*satisfactory result of treatment*
●—*relapse of instability*
▼—*avascular necrosis of the femoral head*
×—*highly retarded ossification in the iliac bone*

skeletal changes of the avascular necrosis [illegible] appeared in one more case, about 12 [illegible] after the plaster treatment

Radiological findings at the most rece[illegible] *amination* One to 4 5 years after diagnosis [illegible] situation of continuing favourable skele[illegible] development was noted in 17 out of the [illegible] previously unstable hip joints, but only [illegible] the girls had completely normal radiograph[illegible] The other 14 hips still showed a [illegible] irregular ossification margin in the iliac bone and/or a smaller head nucleus than on the other side (Figure 1c)

One of the girls with avascular necrosis [illegible] only insignificant skeletal changes [illegible] years of observation Four hips were mark[illegible] by a less favourable skeletal development (Table 4), they are the other hip [illegible] avascular necrosis and three hips in which the mineralization of the acetabulum has been severely retarded (Figure 6)

DISCUSSION

As was noted in the introduction [illegible] and colleagues in Malmo (southern Swe[illegible] have made great progress in [illegible]



Figure 6 Girl, now 5 years and 2 months old. At diagnosis 17 months old, left hip joint reducible after 3 weeks traction, tenotomy and 26 weeks in plaster: stable hip joint. Highly retarded ossification in the left iliac bone. The left bone nucleus of the femoral head is smaller and lies a few millimetres further cranially than the right one

diagnosis. Practically all cases are diagnosed during the neonatal period. This goal has, however, not been achieved in the rest of Sweden. Reports from other countries also show difficulties in connection with neonatal diagnosis (Williamson 1972, MacKenzie 1972, Berkeley 1974, Nelsen 1977). At the neonatal examination, a variety of clinical instability tests are made (e.g., Ortolani, Barlow or Palmén). The problem with these tests is that they sometimes show variable results. This is demonstrated by four cases in this material, which were found to have unstable hips at the maternity clinic. This could only be verified by the orthopaedic surgeon after several examinations. Clinically and radiologically these cases did not, however, differ from the others in the series once the diagnosis was made. Thus it is probable that the other hips also were unstable at birth, but that they were not discovered at this time.

After the neonatal period, the instability is often masked by contractures of the adductor muscle group of the hip. Because of this, the routine instability tests are either difficult or impossible to carry out. Limitation of abduction thus becomes the most common clinical sign (Table 3). This can, however, appear without concurrent instability. Radiographs of the hips are then necessary. Delayed mineralization of the acetabulum can be seen quite early in the lateral part of the iliac bone

Table 4 Four hips (3 patients) with obvious skeletal changes at the final radiological examination

Age at diagnosis (months)	Obs. time after diagnosis (years)	Slight more femoral head nucleus position	Structural changes			Cause
			Caput	Metaphysis	Acetabulum	
4	3.5	+		+	−	Avascular necrosis
1	3.5	+		−		Late diagnosis
21 (bilat.)	1.5	+				Late diagnosis
		+				Late diagnosis



Figure 4 Bilateral arthrography The oldest girl ... stability Arrows (↑) indicate axial pressure on the ... head clearly deformed bilaterally Labrum acetabu... joints

epiphyseal nucleus was clearly smaller on the previously unstable side (*Figure 1b*) In one case this was combined with an irregular and flattened epiphyseal nucleus as well as an irregularity in the metaphyseal bone. Only in one case had the acetabulum become com pletely normal In the others the previously demonstrated lateral defect was completely or partially filled, instead the ossification margin in the iliac bone was more or less irregular (Figure 1b)

During the first year after plaster treatment

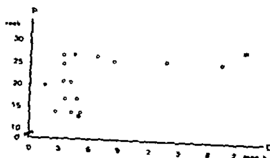


Figure 5 Age at diagnosis (D) in relation to the length of ... Symbols

●

▼—avascular necrosis of the femoral head

×—highly retarded ossification in the iliac bone

skeletal changes of the avascular necros... appeared in one more case about 12 ... after the plaster treatment

Radiological findings at the most rece... amination One to 4 5 years after diagno... situation of continuing favourable sk... development was noted in 17 out of th... previously unstable hip joints, but only ... the girls had completely normal radiogra... The other 14 hips still showed a ... irregular ossification margin in the ili... and/or a smaller head nucleus than on... other side (Figure 1c).

One of the girls with avascular necrosis ... only insignificant skeletal changes after ... years of observation. Four hips were mark... by a less favourable skeletal developm... (Table 4) they are the other hip w... avascular necrosis and three hips in which ... mineralization of the acetabulum has be... severely retarded (Figure 6).

DISCUSSION

As was noted in the introduction ... and colleagues in Malmo (see ... have made great progress ...

3 Restriction of abduction was the most important clinical sign between the neonatal period and the walking age

When a fixed abduction was found, clinical instability could at times only be demonstrated under general anaesthesia after a short period of traction

Even in the youngest cases retarded skeletal development of the acetabulum could be demonstrated

Arthrography is a valuable tool for the verification of hip joint instability, and for finding the optimal position after reduction

The contractures of the hip adductors had to be treated before a good congruency of the joint could be attained.

Treatment in plaster for up to 29 weeks with a change of cast every 4 weeks has been used without great difficulty, and has led to clinically stable hips and a normal gait in all the children

9 With a diagnosis made before walking age, most cases showed good skeletal development of the hip, but avascular necrosis of the femoral head was found in two cases

0 In cases diagnosed after the walking age, radiographs after treatment showed a delayed skeletal development of the acetabulum in certain cases Arthrography indicated a slight residual instability in these hips although they were clinically stable This may necessitate operative procedures in the future

REFERENCES

642–649

Astley, R. (1967) Arthrography in congenital dislocation of the hip *Clin Radiol.* **18**, 253–260

Bjerkreim, I (1974) Congenital dislocation of the hip joint in Norway *Acta orthop scand* Suppl. 157

Faber, A (1938) *Untersuchungen uber die Atiologie und Pathogenese der angeborenen Huftverrenkung* Georg Thieme, Leipzig

Felländer, M, Gladnikoff, H & Jacobsson E (1970) Instability of the hip in the newborn *Acta orthop scand*, Suppl. 130, 36–54

Fredensborg, N (1975) Congenital dislocation of the hip Dissertation, University of Lund

the hip The development of a regional service *J Bone Jt Surg* **54-B** 18–39

Mitchell, G P (1963) Arthrography in congenital displacement of the hip *J Bone Jt Surg* **45** B, 88–95

115–144

Nakamura, K (1968) Arthrographic study of congenital dislocation of the hip joint. *J Japanese orthop Ass* **42**, 53–73

Nielsen H O (1975) Kongenit hofteluxation et 15 års materiale *Ugeskr Laeg* **137**, 2256–2259

Palmén, K (1970) Preluxation of the hip in the newborn. The diagnostic work in Sweden during the years 1953–1966 *Acta orthop scand*, Suppl. 130, 8–12

Palmén, K. (1975) Symposium om hoftledsluxationer Svenska Lakarsallskapets Riksstamma Stockholm

von Rosen, S (1968) *Svensk medicinsk årsbok* Band XI, pp 316–328 Munksgaard, Aalborg

in the treatment of congenital dislocation and subluxation of the hip in the older child *J Bone Jt Surg* **48-A**, 1413–1439

Severin, E (1941) Contribution to the knowledge

diagnosis and treatment of congenital dislocation of the hip in Northern Ireland *J Bone Jt Surg* **54** B, 13–17

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PHYSICAL PROPERTIES OF FLUOROSIS BONE

Critical Comments

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Key words bone disease fluoride poisoning statistics physical bo[illegible] strength tests

In 1976 Franke and co-workers reported a study of the physical properties of bone from patients who had been exposed to fluorine for many years [1] In addition the ash from a rib and an iliac crest was examined and found to contain considerable amounts of fluorine In the mechanical tests, determinations were made of the fracture load and bending strength of complete bones or parts of bones, and of the fracture load per unit of area and the modulus of elasticity of cylindrical test bodies made from bone specimens.

As the thickness of the femoral cortex was greater in the two patients with abnormal amounts of fluorine in the bone than it was in the three control subjects, the tests on the unmodified bone specimens gave a greater strength for the thicker than for the thinner nes. The specific mechanical tests on the cylindrical test bodies yielded the opposite result, the compressive strength being much lower for the bone from the fluorosis patients. In determinations on the same specimens Young's modulus of elasticity was lower in the fluorosis group The micro-hardness determined by Vicker s method was likewise greater for these specimens.

So far, so good But then it was maintained that the observed differences were due to the *fluorosis*, and this conclusion is not [illegible] by the results presented From a sta[illegible] standpoint the observed differences cannot [illegible] regarded as significant simply because [illegible] tests were made on the same specimens F[illegible] valid conclusions regarding differe[illegible] between patient groups a large number o[illegible] *independent* observations is required Observations made on one and the sa[illegible] specimen are not independent

While the observations are consistent [illegible] information in the literature concerning th[illegible] properties of fluoridated bone as [illegible] above, the recorded changes cannot [illegible] certainty be ascribed to the fluorosis Wh[illegible] has been demonstrated is only that cert[illegible] mechanical properties observed in the bo[illegible] of two persons differed from the mechan[illegible] properties observed in the bones of th[illegible] other persons.

Even if a larger patient material had be[illegible] available and an analysis of many [illegible] dent observations had been made it wo[illegible] have only been justifiable to maintain th[illegible] fluoridated bone has different properties fr[illegible] normal bone, it would have remained to b[illegible] proven that these differences were due to th[illegible] fluorosis as such and not to, for example, some other factor that was responsible for both the fluorosis and the hardness of the bone

In a sociological monograph it was shown some years ago that [illegible]

[1] Physical properties of fluorosis bone J Franke H Runge, P Grau, F Fengler C Wanka & H Rempel, *Acta orthop scand.* 47, 20–37 1976

with a large area of parquet flooring in their home were on average significantly happier in their married life than couples with only a small area of such flooring Even so no family counsellor would consider prescribing an increase in the area of parquet flooring as a recipe for connubial bliss Conclusions of this kind are not acceptable in science whether in sociological or in orthopaedic contexts.

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Acta orthop scand 49, 382–383, 1978

PHYSICAL PROPERTIES OF FLUOROSIS BONE

Critical Comments

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Key words bone disease fluoride poisoning, statistics physical [illegible] strength tests

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In a sociological monograph [illegible] shown some years ago that married [illegible]

[1] Physical properties of fluorosis bone J Franke, H Runge, P Grau, F Fengler C Wanka & H Rempel, *Acta orthop scand* 47, 20–37 1976

around the prosthesis not exceeding 2 mm (*Normal*).

The first radiological signs of loosening of the prosthesis are discrete, more than 2 mm wide areas of radiolucency at the sites of maximal weight-bearing (collum and tip of femoral stem). Acetabular wear will show radiolucency in the acetabular roof and eventually osteophyte formation (*Discrete radiolucency*).

A more than 2 mm wide irregular zone of radiolucency around a large part of the femoral stem is indicative of advanced loosening or [illegible]

[illegible] was determined regularly. An ESR exceeding 25 mm/hour more than 3 months after implantation was regarded as indicative of infection (Sjostrand 1974).

A ^{99m}Tc-pyrophosphate scintigraphy was performed, in patients D and N $6\frac{1}{2}$ months after implantation of the prosthesis, while the others were examined more than 10 months after surgery. One patient (O) was reoperated on less than half a year after implantation of the first prosthesis, thus no scintigraphy was performed.

The scintigram will either show *heavy diffuse accumulation* surrounding the prosthesis (indicative of infection), *discrete* but *heavy accumulation* around a small part of the prosthesis (indicative of a mechanical problem) or very weak accumulation (*normal*).

By means of patch tests, allergy to chromium, cobalt and nickel was investigated (Evans et al. 1974).

Of the 16 patients, 13 were reoperated on. In 11 patients the prosthesis was replaced, including five after previous fenestration of the femoral cortex. In two patients only fenestration of the femoral cortex was performed. During reoperation, swabs for aerobic, anaerobic and hypertonic sachrose – broth cultures (Kamme et al. 1974, Nolan et al. 1975) and biopsy specimens were obtained from the medullary cavity.

RESULTS

Each of the 16 patients is denoted by a letter.

Table 1 shows the results of the non-operative studies. The patients fall into two groups.

Group 1 This consists of nine patients (B, G, I, J, K, L, N, P [and O]) in whom at least two of the three examinations were suggestive of *infection* and in whom there was good agreement between the radiographic and scintigraphic findings (i.e., the patients in the right upper corner of the table). The diagnosis of infection was

Table 1 The results of radiographic, serological and scintigraphic examinations and their interrelation

Scintigraphy \ X ray	ESR (mm/hour)	Normal	Discrete radiolucency	Diffuse irregular radiolucency	Ostitis
Heavy diffuse accumulation	>25			P	IBGK
	<25	M	C	L	N
Heavy, localized accumulation	>25		F	J	
	<25				
Normal	>25	H			
	<25	A E	D		

Patient O (with infection) was not subjected to scintigraphy and is therefore not included in the table.

afterwards confirmed in all cases except patient P, in whom re-operation revealed complete loosening of the prosthesis *without* bacteriological or histological signs of infection This patient had for a short time been given lincomycin without any change in symptoms or findings (including ESR)

Group 2 This group consists of seven patients (A, C, D, E, F, H and M) in whom none or at most one of the results of the examinations was compatible with the presence of *infection* The results in this group are more variable None of the patients in group 2 has subsequently been found to suffer from infection

No patient in group 2 had X-ray findings indicative of infection However, scintigraphy of patients C and M showed heavy, diffuse accumulation around the prosthesis. In patient M the scintigraphic accumulation was caused by allergy but in patient C no reason was found In only one of the patients with positive findings (F) was there agreement between radiography and scintigraphy and in this patient scintigraphy disclosed the cause of pain heavy accumulation in the roof of the acetabulum Correspondingly, reoperation disclosed abundant granulation tissue presumably because of too large a prosthesis head. X-ray only revealed slight radiolucency in the acetabular roof and osteophyte formation.

Table 2 shows the most likely cause of the inflammation around the prosthesis based on bacteriological and histological findings as well as on radiography, sero-reactions and scintigraphy Decisive diagnostic importance was ascribed to the bacteriological and histological findings.

The patients were re-examined more than 22 months after treatment of their painful arthroplasty The results are shown in Table 3 Only three patients were pain-free. The patients denoted "improved" had slight pain on weight bearing mostly using a cane when walking outdoors and one patient (B) had a persisting fistula. The three patients whose condition had deteriorated had severe pain at rest and very poor ambulatory function. In patient L a Girdlestone arthroplasty was performed 1½ years after replacement of an infected hip prosthesis and the same procedure is planned for patient N The table shows that only three of the eight infected patients felt better after treatment, which in all cases included antibiotics. Likewise two of the three patients whose discomfort increased unacceptably had an infected prosthesis.

Table 2 The aetiology of the ostitis around the hip prosthesis The diagnosis was based on as many findings as possible, but if a given patient had undergone re-operation it was based particularly on the bacteriological and histological findings

Aetiology	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Infection																
Mechanical irritation*																
Allergy																
Unknown																
Re-operated																

* Loosening or uneven mechanical pressure
A black rectangle indicates the most probable aetiology and that the patient had undergone re-operation.

Table 3 The results of treatment of failed hip arthroplasty based on interviews with the patients more than 22 months after treatment

Symptoms after treatment	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Well				■		■									■	
Improved	■	■	■								■					
Unaltered					■		■		■	■			■			■
Worse								■				■		■		

DISCUSSION

Osseous inflammation around a prosthesis , give only very weak X-ray changes within e first year after implantation of the prosthesis (Bergstrom et al 1973, Charnley 1972), partly because of a slow course and partly because some destruction of the surrounding osseous tissue is required before pathological radiolucency can be distinguished radiographically from normal radiolucency Accumulation on a scintigram is caused by increased metabolism and vascularity (Jones et al 1976) Any noxious stimulus (e g , infection, allergy and loosening) will very soon cause these principal elements of inflammation Scintigraphy thus gives a picture of inflammation and does not demand morphological destruction before a positive finding can be registered A successfully implanted prosthesis will show a normal scintigram after half a year (Bauer et al 1973)

Sjostrand (1974) performed both scintigraphy and scintimetry, and he found that these investigations together gave indications of whether the prosthesis was infected or loosened. Scintigraphy, as performed in this study, reveals the presence of inflammation and where it is situated, but it is not possible to differentiate infection from loosening by the intensity of inflammation

We find scintigraphy valuable in two situations When a patient experiences pain despite an almost normal radiogram (e g , patients C, F and M), and when X-ray shows radiolucency, to determine whether it is caused by an active or an inert process (e g , patient D)

In the case of infection, radiography and scintigraphy show identical and diffuse abnormalities. The diagnosis of infection can be confirmed by fenestration of the femoral cortex This operation may also give material for histological studies (Charosky et al 1973) and cultures (Kamme et al 1974) thus helping to choose the best antibiotic Further fenestration might relieve pain (Arnoldi & Buhl 1973, Wilson & Scales 1970)

Before reoperation allergy should be looked for

REFERENCES

Bauer, G C. H Lindberg L. Naversten Y & Sjostrand L.-O (1973) [85]Sr radionuclide scintimetry in infected hip arthroplasty *Acta orthop scand* 44 439–450

Bergstrom, B Lidgren, L., Lindberg L Persson ... O (1973) Infection after ... *Lak Tidn*

...ction after ... reference to air contamination in the operating room *Clin Orthop* 87, 167–187

Charosky, C. B, Bullough, P G & Wilson, P D (1973) Total hip replacement failures. *J Bone Jt Surg* 55-A, 49–58

Evans, E M, Freeman, M A R & Vernon-Roberts, B (1974) Metal sensitivity as a cause of bone necrosis and loosening of the prosthesis in total hip replacement. *J Bone Jt Surg* 56-B, 626–642.

Feith, R, Slooff, T J J H, Kazem, I & van Rens, T J G (1976) Strontium ^{87}Sr bone scanning for the evaluation of total hip replacement *J Bone Jt Surg* 58 B 79–83

Jones A G, Francis, M D & Davis, M A (1976) Bone scanning radionuclide reaction mechanisms. *Semin Nucl Med* 6, 3–18

Kamme, C, Lidgren, L, Lindberg, L & Mardh, P-Å (1974) Anaerobic bacteria in late infections after total hip arthroplasty *Scand J infect Dis* 6, 161–165

Nolan, D R, Fitzgerald, R H Jr, Beckenbaugh, R D & Coventry, M B (1975) Complications of total hip arthroplasty treated by reoperation. *J Bone Jt Surg* 57 A, 977–981

Salvati, E A, Freiberger, R H & Wilson, P D (1971) Arthroplasty for complications of total hip replacement *J Bone Jt Surg* 53-A, 701–709

Salvati E A, Ghelman, B, McLaren, T & Wilson P D (1974) Technique of arthrography for loosening of total hip replacement fixed with radiopaque cement. *Clin Orthop* 101, 105–109

Sjostrand, L-O (1974) Radionuclide assessment of total hip arthroplasty University of Lund Sweden

Wilson, J N & Scales, J T (1970) Loosening of total hip replacements with cement fixation. *Clin Orthop* 72 145–170.

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SECULAR TENDENCIES OF THE INCIDENCE OF FRACTURE OF THE UPPER END OF THE FEMUR

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[illegible]

and 1975 was calculated taking into account the changes in the size and the composition of the population It was demonstrated that during the first period the previously described increasing trend continued so that more fractures were observed than could be expected from changes in the population only, whereas later on this trend became insignificant The changes observed after 1968 could be explained by the increasing number of old residents in the city, and there was no obscure secular trend

Key words fracture, incidence, femoral neck

Accepted 6 ii 78

Alffram (1964) found that during the period 1949–1961 the risk of femoral neck fracture increased in the city of Malmo The increase exceeded that which could be explained by changes in the age of the population at risk, even when the increased survival age was accounted for, the number of fractures increased over the years Mårtenson (1962), also, pointed out that the risk appeared to increase in the city of Gothenburg

These findings suggest that an additional, so far unknown, aetiologic factor is interfering with the incidence pattern

The objective of the present study was to continue these observations of fracture incidence up to the present time in order to decide whether or not this secular trend is continuing

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MATERIAL AND METHODS

From the records of the Departments of Radiology and Orthopaedic Surgery, all cases of fracture of the upper end of the femur, trochanteric and cervical, in residents of the city of Malmo, were collected for the years 1967 1968, 1974 and 1975 On the basis of the census data of the city the age and sex specific incidence of the injuries was calculated. The expected numbers of fractures for the years 1967, 1968, 1974 and 1975 were calculated on the basis of the incidence in 1951–1960 assuming that the risk had remained unchanged over the years By calculating the expected numbers within each 10-year age group the changes in age distribution over the years were accounted for The observed numbers were then compared with the expected by means of Poisson statistics (cf Alffram 1964).

RESULTS

In the period 1951–1960 the average annual number of fractures of the upper end of the femur in the city of Malmö was 132 In 1967–1968 the numbers had increased to 266

and 246, respectively, and finally, in 1974 and 1975 the numbers observed were 331 and 311 There was an appreciable increase in the number of fractures However, when the observed numbers were compared with the expected, derived from the population figures, and the numbers observed by Alffram (1964) it could be demonstrated that there was a significant continuing increase in the trend between the fifties and 1967–1968 (Figure 1) From that time on the observed number in comparison with the expected did not increase significantly The age and sex specific incidence is demonstrated in Figure 2. There was a tendency towards a continuing increase in the incidence in the oldest age groups even during the interval 1967/68 to 1974/75 However, the very oldest patients, the octogenarians, were too few in number to contribute significantly to the rising trend, particularly the men In women, there was a significant trend of an increasing average age at the time of fracture for both cervical and trochanteric fractures (Table 1)

Table 1 Mean age at the time of fracture

		1951–60	1967–68	1974–75
Men	Cervical	68 6	71 2	71 7
	Trochanteric	69 4	69 3	71 4
Women	Cervical	71 7	72.7	76 7
	Trochanteric	75 2	76 6	78 0

DISCUSSION

The population background for the increasing number of fractures should be considered In the city of Malmo over the last two decades, there has been a change in the distribution of the population, as demonstrated in Figure 3 A population peak resulting from a high birth rate at the turn of the century has advanced 20 years, which may be the basic cause of the increasing number of fractures However, until 1968 the number of fracture in the city increased more than could be explained by the changes in the population only There is

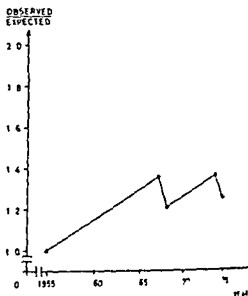


Figure 1 The relationship between observed and expected number of fractures of the upper end of the femur Variations after 1967 are not significant

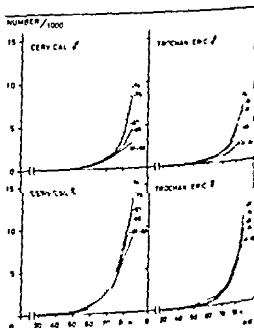


Figure 2 Age and sex specific incidence of fractures of the upper end of the femur Note that there was an increase also during the period 1967–68 to 1974 75 in the oldest group even in women As regards trochanteric fractures in women the increase was, however, not significant

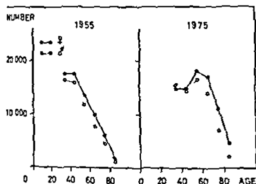


Figure 3 Population of the city of Malmo in 1955 and 1975 A peak value can be seen which is a result of migration and possibly a high birth rate during the second decade of this century This population peak still has not had its full effect on the fracture pattern in the city

no valid explanation for this A hypothesis is that those patients, who had their fractures in the sixties, in many instances had been raised in the city of Malmo in the late phase of the industrial revolution with poverty and insufficient nutrition whereas a decade earlier persons who then sustained fractures had mostly grown up in the country in southern Sweden and later moved to the city

Moreover, the effects of poor nutrition in Swedish cities during the 1st World War cannot be disregarded Alffram (1964) found that fracture of the upper end of the femur is more common in individuals born in the fall than in the spring which indicates that factors such as food and vitamin deficiencies in childhood may be of importance

It appears as if the rising trend has been broken so that in the future the expected number of fractures may, with some accuracy be calculated from the expected distribution of the population with regard to age and sex and that an increasing number of old residents will have the expected number of fractures and no more It is of interest to study the incidence changes also in the future

REFERENCES

Alffram P A (1964) An epidemiologic study of cervical and trochanteric fractures of the femur in an urban population *Acta orthop scand Suppl. 65*

Mårtenson L (1962) Är svensk sjukhusplanering ändamålsenlig? *Svenska Läk Tidn.* 44, 3185–3200

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UNSTABLE TROCHANTERIC FRACTURES TREATED WITH THE SLIDING SCREW-PLATE SYSTEM

A Biomechanical Study of Unstable Trochanteric Fractures III

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Eighty unstable trochanteric fractures were treated with the [illegible] plate system. Early weight-bearing was encouraged and [illegible] obtained within the first week in 47 per cent of the cases (37/79). [illegible] complications were encountered in 5 per cent of the patients [illegible] none required re-operation. Telescoping of the screw occurred in [illegible] cent (37/76). Through this secondary fracture impaction a [illegible] transmission system was established. Fracture union in the [illegible] position was obtained in 49 per cent of the patients (37/76) and [illegible] did not occur.

Key words: osteosynthesis; rehabilitation; trochanteric femoral [illegible]

Accepted 5.i.78

The major problems encountered in the internal fixation of trochanteric fractures are mechanical, especially in unstable fractures (Evans 1949) where the implant alone has to transmit the load from the hip joint to the femoral shaft (Jensen 1978). The load on the hip joint during normal level walking has been calculated to be about six times the body weight (Paul 1971).

The technical complications experienced are either penetration or cutting by the nail due to osteoporosis of the femoral neck and head or bending and breakage of the hip nail-plate due to cyclic loading of the implant, which can also lead to pulling out of the screws. Internal fixation with conventional hip nail-plates of the Jewett type has been followed by technical complications of this nature in 16–51 per cent of cases (Dimon & Hughston 1967, Parker 1955, Robey 1956, Sarmiento 1963, Wade et al. 1959) and with the McLaughlin type in 15–44 per cent of cases (Foster 1958, Friedenberg et al. 1972, Jensen & Michaelsen 1975, Laros & [illegible] 1974).

In 1964, Clawson introduced the [illegible] screw-plate system for internal [illegible] trochanteric fractures and rather [illegible] results have been reported recently (Ecker et al. 1975, Harrington & Johnston [illegible], Mulholland et al. 1972). In the present [illegible] our preliminary experiences with this [illegible] method will be reported.

PATIENTS AND METHODS

During the period January 19[illegible] to July 19[illegible] the sliding screw-plate system was used for the treatment of 80 unstable trochanteric fractures. The method was applied in fractures classified as unstable either due to lack of posteromedial bone support or lack of medial bone support over the fracture line or a combination of these [illegible] (Evans 1949).

The average age of the patients was [illegible] (range 40–96 years) and 45 per cent [illegible]

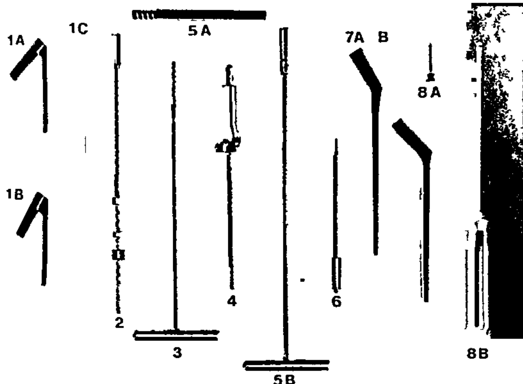


Figure 1 Instrumentation for the insertion of the sliding screw-plate
1 A + B + C 135° angle guide and 150° angle guide with K wire
2 cannulated central reamer
3 cannulated lag screw tap
4 cannulated barrel reamer
5 A hexagonal hip lag screw
5 B cannulated lag screw insertion wrench
6 barrel guide
7 A + B 135° and 150° side plate with 5 holes
8 A + B compression screw with screwdriver

women. Seven patients died within 3 months after the operation giving a mortality rate of 8 8 per cent (7/80) Seventy three patients were followed until fracture union was achieved In this follow-up series an additional three patients are included as technical complications or telescoping of the screw were encountered before their death.

The operation was performed with the patient supine on a fracture table under X-ray image intensification. After attempted anatomical reduction of the fracture a lateral surgical exposure was made. The instrumentation needed for the internal fixation is shown in Figure 1 A guide wire was passed through the angle guide and drilled through the lateral femoral cortex and the femoral neck into the subchondral area of the femoral head. After measuring the protruding length of the guide wire this was tapped through the acetabular roof so that it would not be accidently removed during the following steps. A channel for the screw was reamed and tapped and in addition the lateral femoral cortex was reamed for the barrel of the side-plate. A hip lag screw of suitable length (~1 5 cm less than the distance from the subchondral area to the lateral cortex) was inserted over the guide wire and fastened firmly in the subchondral area. By means of a barrel guide the side-plate was positioned over the screw In this series the Howmedica Inc. modification (catalogue No 6465-0-000) was used with a barrel-plate angle of 135° or 150° Rotational stability is secured by an edge in the round barrel and the hexagonal shape of the screw After having fixed the plate to the femoral shaft the traction was released and compression applied over the fracture line by means of

special compression screw, which was removed after impaction

In cases with greater medial diastasis in the fracture line a primary medial displacement of the femoral shaft was performed in order to establish bony contact

Mobilization with full weight bearing was encouraged after the first postoperative period of 2–3 days and postoperative X ray examinations were performed at 3 weeks, 6 weeks and 3 months. In the follow up study the primary X-rays and subsequent review X-rays were evaluated taking into consideration the technical results.

RESULTS

In the present series 58 screw-plates with an angle of 135° and 22 with an angle of 150° were applied

The distribution of the fracture types according to Evans (1949) is shown in Table 1, 61 per cent (49/80) of the fractures were 4-fragmentary

Early weight-bearing was encouraged and Figure 2 demonstrates the time interval before full weight-bearing was achieved, in 47 per cent (37/78) it was within the first week.

The reduction of the fracture was evaluated on the postoperative X-rays and the results are shown in Table 2. In 44 per cent (35/80) of the cases a mechanically stable reduction which allowed load transmission

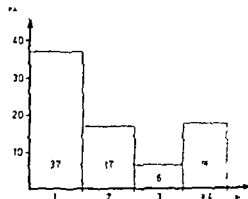


Figure 2 Time interval before full [illegible] achieved (78 patients – 2 [illegible] mobilization)

through bony contact was obtained. [illegible] cases stability was established through medial shaft displacement and in one case through anatomical reduction and screw fixation of the lesser trochanter In the remaining cases there was a diastasis of more than 0 5 cm [illegible] the fracture line

The results of the follow-up of the [illegible] patients are shown in Table 3 There was one case of deep infection but no instance of [illegible] union Forty nine per cent of the fractures (37/76) healed in the postoperative position. Telescoping of the screw took place in 49 per cent (37/76) In 29 of these 37 cases the reduction was considered mechanically unstable as judged by the postoperative X ray As a result of this secondary [illegible]

Table 1 Classification of unstable trochanteric fractures (Evans 1949)

3 fragmentary without postero-lateral support	23
3 fragmentary without medial support	8
4-fragmentary	49
Total	80

Table 2 Radiological fracture reduction in 80 unstable trochanteric fractures

Mechanically stable reduction	35
– screw fixation of lesser trochanter	1
– medial displacement of femoral shaft	17
Medial or lateral diastasis ≥0 5 cm	21
Anterior or posterior diastasis ≥0 5 cm	24

Table 3 Radiological follow-up [illegible] trochanteric fractures

Fracture union in postoperative position	[illegible]
Telescoping of the screw	[illegible]
Technical complication	[illegible]

Table 4 Technical complications [illegible] trochanteric fractures

Penetration of the screw head	[illegible]
Cutting of the screw head	[illegible]

The screw head was displaced outside [illegible] finements of the femoral head.



Figure 3 A, B Postoperative reduction of the fracture Note anterior diastasis on the sagittal roentgenogram C Result after telescoping and established bony support after 3 weeks of full weight bearing

ment of the fracture a stable load transmission system through bony contact was obtained. Figures 3 and 4 demonstrate cases where sliding of the screw took place and resulted in a mechanically reliable system The telescoping took place within the first 4 weeks in the majority of cases (29/37) The patients often complained of pain during weight bearing in this period

Technical complications were encountered in 5 per cent of the patients (4/76) as shown in Table 4 In all these patients the screws were placed less than 10 mm from the cartilaginous border Penetration as well as cutting of the screw resulted in a varus angulation of the fracture In two cases this amounted to less than 10° and to 20–30° in the other two Bony contact, however, was established and the fracture healed in the varus position No further treatment was needed.

DISCUSSION

Most authors dealing with unstable trochanteric fractures treated with conventional hip nail-plates recommend non-weight-bearing until the fracture has healed (Laros & Moore 1974, Parker 1955, Robey 1956) In the series reported by Jensen & Michaelsen (1975) 15 per cent (25/169) significant mechanical complications (i e, penetration of the nail, bending loosening or breakage of the nail or plate) were encountered although a postoperative period of non weight bearing of 8 weeks was practised. In the first report on the sliding screw plate Clawson (1964) recommended non-weight bearing until fracture union was encountered, but later series permitted early weight-bearing (Ecker et al. 1975, Harrington & Johnston 1973, Mulholland et al 1972, Sahlstrand 1974) Bosacco et al. (1973) and

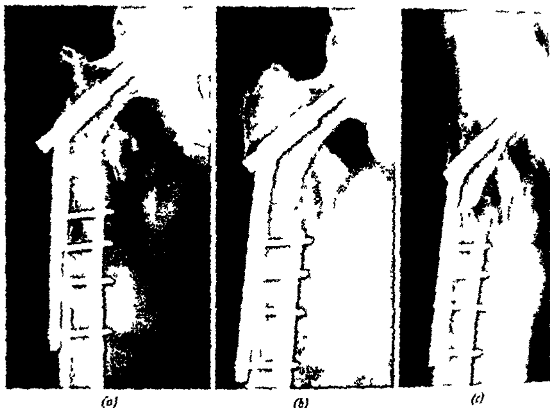


Figure 4 A Postoperative reduction of 4 fragmentary fracture Note medial diastasis B Telescoping has taken place after 2 weeks of full weight-bearing C Healing result in mechanically stable position

Sahlstrand (1974) stressed the importance of early mobilization in the treatment of these elderly often debilitated patients. It is possible that the unusually low mortality rate in our series might be a consequence of the early mobilization

As regards the technical complications following internal fixation of unstable trochanteric fractures the complication rate in series of Jewett nail-plate osteosynthesis has been about 30 per cent (Robey 1956, Wade et al. 1959), although Parker (1955) stated 15 per cent and Dimon & Hughston (1967) as many as 51 per cent The McLaughlin nail-plate system seems to give slightly better results with complication rates of 15–23 per cent in most series (Foster 1958, Jensen & Michaelsen 1975 Laros & Moore 1974), although Friedenberg et al. (1972) stated 44 per cent. In contrast to this, however, encouraging results have been reported from USA with the use of the sliding screw-plate system with technical complication rates as low as 4–7 per cent (Ecker et al. [illegible] Harrington & Johnston 1973 Mulholland et al. 1972). Friedenberg et al (1972), however, encountered complications in 19 per cent in a small series of 27 cases including [illegible] per cent that were re-operations. In the present series technical complications were found in only 5 per cent of cases (4/7[illegible]. We fully approve of the basic idea of the sliding screw-plate fixation, viz., that a primary stable internal fixation is unobtainable in these osteoporotic three- and four-fragmentary fractures. The telescoping effect allows the fracture ends to impact during weight-bearing until bony support is established across the fracture line. In the present series telescoping of the screw actually took place in 49 per cent of the cases (37/76). Reports on this subject are difficult to compare as no one fracture classification system is generally accepted. In the present

series the Evans classification (1949) was used as it also was in a previous paper by one of the authors (Jensen & Michaelsen 1975). The radiological evaluation was based on the same principles too. In the 1975 series (Jensen & Michaelsen) significant technical complications were encountered in 15 per cent of cases (25/169) following McLaughlin osteosynthesis. This necessitated re-operations in 6 per cent (10/169). In the present series technical complications were encountered in only 5 per cent (4/76) of cases and no re-operations were necessary.

In conclusion we find the sliding screw-plate system to have distinct advantages, because it allows early weight-bearing which is essential for successful rehabilitation and because the telescoping leads to bony support which is essential for the mechanical load transmission.

REFERENCES

Bosacco, D. N., Breman, A. T., Cesare, J. G., Fabiani, J. A. & Conner, J. H. (1973) Early weightbearing for intertrochanteric fractures. Amer. Academy Orthop. Surg., Meeting in Washington D.C.

Clawson, D. K. (1964) Trochanteric fractures treated by the sliding screw plate fixation method. *J. Trauma* 4, 737–752.

Dimon, J. H. & Hughston, J. C. (1967) Unstable intertrochanteric fractures of the hip. *J. Bone Jt Surg.* 49-A, 440–450.

Ecker, M. L., Joyce III, J. J. & Kohl, E. J. (1975) The treatment of trochanteric hip fractures using a compression screw. *J. Bone Jt Surg.* 57 A, 23–27.

Evans, E. M. (1949) The treatment of trochanteric fractures of the femur. *J. Bone Jt Surg.* 31 B 190–203.

Foster, J. C. (1958) Trochanteric fractures of the femur treated by the vitallium McLaughlin nail and plate. *J. Bone Jt Surg.* 40 B, 684–693.

Friedenberg, Z. B., Gentchos, E. & Rutt, C. (1972) Fixation in intertrochanteric fractures of the hip. *Surg. Gynec. Obstet.* 135, 225–228.

Harrington, K. D. & Johnston, J. O. (1973) The management of comminuted unstable trochanteric fractures. *J. Bone Jt Surg.* 55-A 1367–1376.

Jensen, J. Steen & Michaelsen, M. (1975) Trochanteric femoral fractures treated with McLaughlin osteosynthesis. *Acta orthop. scand.* 46, 795–803.

Jensen, J. Steen (1978) A photoelastic study of the hip nail plate in unstable trochanteric fractures. *Acta orthop. scand.* 49, 65–67.

Laros, G. S. & Moore, J. F. (1974) Complications of fixation in intertrochanteric fractures. *Clin. Orthop.* 101, 110–119.

Mulholland, R. C., Gunn, D. R. & Orth, M. C. (1972) Sliding screw plate fixation in intertrochanteric femoral fractures. *J. Trauma* 12, 581–591.

Parker, S. G. (1955) Analysis of one hundred and fifty consecutive intertrochanteric fractures of the femur. *J. Int. Coll. Surg.* 24, 202–214.

Paul, J. P. (1971) Load actions on the human femur in walking and some resultant stresses. *Exp. Mechanics* 11, 121–125.

Robey, L. R. (1956) Intertrochanteric and sub trochanteric fractures of the femur in the negro. *J. Bone Jt Surg.* 38 A, 1301–1312.

Sahlstrand, T. (1974) The Richards compression and sliding hip screw system in the treatment of intertrochanteric fractures. *Acta orthop. scand.* 45, 213–219.

Sarmiento, A. (1963) Intertrochanteric fractures of the femur. *J. Bone Jt Surg.* 45-A, 706–722.

Wade, P. A., Campbell, R. D. & Kerin, R. J. (1959) Management of intertrochanteric fractures of the femur. *Amer. J. Surg.* 97, 634–643.

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Figure 4 A Postoperative reduction of 4-fragmentary fracture Note medial diastasis. B Telescoping has taken place after 2 weeks of full weight bearing C Healing result in mechanically stable position.

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to the edge of the table Dodging was also employed (Levén 1974) The examinations were performed by several different radiologists

Arthroscopy

Our technique of arthroscopy is described elsewhere (Gillquist & Hagberg 1976) Briefly the 5 mm Storz arthroscope (Stille–Werner, Sweden) is introduced into the suprapatellar bursa through the patellar tendon Sterile water is flushed through the joint by an infusion pump (Sarns Model 5500, Stille–Werner, Sweden) and allowed to escape through a special needle (arthroscopy cannula Stille–Werner, Sweden) inserted into the suprapatellar bursa Hooks (Gillquist & Hagberg 1976) are used to test the menisci and the cruciate ligaments. Four surgeons performed most of the arthroscopies but about 10 per cent of the examinations were done by another five surgeons under training

Operation

In all our patients the history and clinical findings indicated arthrotomy, and all were therefore operated on irrespective of the findings at arthrography or arthroscopy

Comparison of the findings

The findings at arthroscopy and arthrography differed in many respects The results of the two modes of investigation are compared with the operation findings A diagnosis was considered accurate when all injuries found at operation had been reported by both arthroscopist and radiologist However rupture of the medial collateral ligament was excluded in all combined injuries as this was difficult to diagnose by either method especially in old injuries

Statistical methods

The usual statistical methods were used (Armitage 1974)

RESULTS

Table 1 shows the diagnoses in the entire series as well as in the 90 patients examined by arthrography and arthroscopy in this hospital The diagnostic findings at arthroscopy and arthrography agreed with the operation findings in 45 cases (Figure 1) In seven knees arthroscopy failed whereas X-ray gave the correct diagnosis. Thus the roentgen

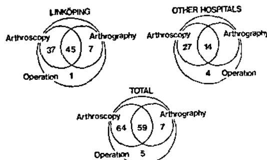


Figure 1 The correlation of findings at [illegible] and arthroscopy with the findings at

findings tallied with the operation findings in 52 out of the 90 knee joints operated on (58 per cent) Of the 38 patients in whom arthrography gave an inaccurate diagnosis arthroscopy succeeded in 37 In one patient both X-ray and endoscopy failed and operation was performed on clinical grounds The arthroscopic findings tallied exactly with the findings at operation in 82 of the 90 patients (91 per cent)

Inaccurate diagnoses

Arthroscopy The diagnosis was inaccurate in eight patients (9 per cent) (Figure 2) Six patients were examined during the first year of the study period, when the failure rate (6/26) was significantly higher than during the rest of the period (2/64) ($P<0{\cdot}01$)

The reason for failure was technical in two cases, when we used a 4 mm arthroscope (Storz) In five patients there was a linear rupture of the posterior horn of the medial meniscus Two patients had a tear of the medial meniscus combined with rupture of the anterior cruciate ligament in one case the arthroscopy demonstrated the ruptured ligament but not the meniscus tear, and in the other a second arthroscopy disclosed the injuries. In the eighth patient the diagnosis of ruptured medial meniscus was made by arthroscopy (X-ray normal) and at operation

series suggests that arthroscopy should be done when arthrography is negative

The cruciate ligaments are difficult to examine by arthrography especially in the acute stage In the present study 35 per cent of ruptured anterior cruciate ligaments were not diagnosed, even though sagittal traction was applied (Liljedahl et al 1966 Levén 1974) A further improvement in the roentgen diagnoses of ruptures of the anterior cruciate ligament has been proposed by Levén (1977a, b), the sagittal instability being measured on films exposed during sagittal traction. Even under direct observation however, a tear may be masked by the synovia, but the lesion is easily demonstrated with a hook.

Arthroscopy has several advantages over arthrography It is possible to inspect the lesions in conditions such as synovitis (Watanabe et al. 1969 O Connor 1973) chondromalacia and osteoarthrosis (Jackson 1974 Gillquist & Hagberg 1976), and acute injury (Gillquist et al. 1977), and therapeutic procedures can be performed transcutaneously (Gillquist et al. 1976).

ACKNOWLEDGEMENT

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REFERENCES

Alm, A., Gillquist, J & Liljedahl, S-O (1974) The diagnostic value of arthroscopy of the knee joint. *Injury* 5, 319–324

Armitage, P (1974) *Statistical methods in medical research.* Blackwell Scientific Publications, London.

Butt, W P & McIntyre J L. (1969) Double-contrast arthrography of the knee. *Radiology* 92, 487–499

Correspondence to Jan Gillquist, Department of General S
58185 Linkoping Sweden.

Eikelaar H R. (1975) *Arthroscopy of the knee.* Thesis. Royal United Printers Hoitsema V V The Netherlands.

Gillquist, J & Hagberg G (19 6) A new modification of the technique of arthroscopy of the knee joint. *Acta chir scand.* 142, 123 130.

Gillquist, J Hagberg G & Oretorp N (1976) Terapeutisk artroskopi (in swedish). *Svensk Lak. Tidn* 73, 2039

Gillquist, J., Hagberg G & Oretorp N (1977) Arthroscopy in acute injuries of the knee joint. *Acta orthop scand* 48 190–196

Haage H & Watanabe, M. (1973) Arthrographie und Arthroscopie Betrachtungen über die Wertigkeit der Methoden. *Z Orthop* 111, 178–183

de Haven, K. B & Collins, H. R. (1975) Diagnosis of internal derangements of the knee. *J Bone Jt Surg* 57 A, 802–810

Jackson, R. W (1974) The role of arthroscopy in the management of the arthritic knee. *Clin Orthop* 101, 28–35

Jackson, R. W & Abe, I (1972) The role of arthroscopy in the management of disorders of the knee *J Bone Jt Surg* 54-B 310–322

Kennedy J C. & Fowler P J (1971) Medial and anterior instability of the knee. *J Bone J Surg* 53-A, 1257–1270

Levén, H (1974) Arthrography of the knee with a modified technique. *Acta radiol. (Stockh.)* 15 237–240

Levén, H. (1977a) Radiological determination of the sagittal instability of the knee joint. *Acta radiol. (Stockh)* (In press.)

Levén, H (1977b) Evaluation of a modified method for arthrography of the knee. *Acta radiol. (Stockh)* (In press).

Liljedahl, S-O., Lindvall, M. & Wetterfors J. (1966) Roentgen diagnosis of rupture of anterior cruciate ligament. *Acta radiol. (Stockh.)* 4 225–239

Lindblom, K. (1948) Arthrography of the knee Roentgenographic and anatomic study *Acta radiol. (Stockh)* Suppl. 74

Nicholas, J A., Freiberger R. H. & Killoran, P J. (1970) Double-contrast arthrography of the knee. *J Bone Jt Surg* 52 A, 203–220

O Connor R. L. (1973) The arthroscope in the management of crystal induced synovitis of the knee. *J Bone Jt Surg* 55 A 1443 1449

Sylvin, L. E. (1975) A more exa[illegible] surement of the sagittal [illegible] of th[illegible] *Acta orthop s*[illegible] 1 [illegible]

Watanabe, [illegible] 1969 *Atlas o*[illegible]

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MENISCECTOMY

A Comparison of Two Series Treated as Outpatients and Inpatients

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A total of 129 patients were operated on for meniscus lesion in the knee joint. Of these, 64 were operated as outpatients and 65 as inpatients. The outpatients reported to the operation department in the morning and left the hospital in the evening of the same day, after the operation. The inpatients were admitted to the hospital the day before the operation and were discharged 1–3 days after the operation

Objective postoperative findings, sick leave periods and the number of visits to the outpatient clinic show no differences between the groups. The end result in the two groups is the same.

This investigation also shows that it is possible to operate on patients with meniscus injury as outpatients without increased discomfort for the individual and without medical risks. Thus expensive nursing resources are released for other groups requiring more nursing care

Key words knee joint, meniscus, operation treatment

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Patients operated on for meniscus injury require a considerable number of bed-days annually at orthopaedic surgical clinics. According to the literature, the nursing period varies from 3 days to 3 weeks (Smillie 1962, Helfet 1963, McGinty et al. 1977) The patient is usually admitted on the day before operation and discharged 1 to 4 days after

In order to reduce the load on the nursing departments, we began, in 1974, a policy of operating on, as outpatients, specially chosen patients with meniscus injury Healthy men 20 to 40 years of age with a clinically and arthrographically verified meniscus injury were usually chosen for outpatient operation All lived within 30 minutes travelling time from the hospital It was soon realized that operated outpatients managed just as well as inpatients. Therefore outpatient operation was extended to other age groups.

The object of this study was to determine whether the outpatient operation increased the medical risk and the subjective discomfort of the patients.

PATIENTS AND OPERATIVE PROCEDURE

The study involved 129 patients 94 men and 35 women. All those operated on as outpatients were studied during a definite period. A control series with the same age range was randomly chosen from among the operated inpatients.

All patients were examined one or more times in the outpatient clinic before the operation All were X rayed to exclude skeletal changes. Only half of them (62 patients) underwent arthrography 35 inpatients and 27 outpatients. At the

Table 1 Age and sex distribution

Age	Male		Female	
	Outpatients	Inpatients	Outpatients	Inpatients
< 20	5	6	2	4
21–30	15	11	5	3
31–40	14	14	7	6
41–50	9	11	2	5
> 51	5	4	0	1

There are no significant differences between the number of patients in the respective age groups (male group $Chi^2 = 2\ 53$, d f = 4, $P > 50$ per cent, female group $Chi^2 = 2\ 73$, d f = 4, $P > 50$ per cent)

preoperative examination, all were informed about the nature of the injury and of the proposed operation and postoperative treatment In each group, 46 patients (2/3) were given detailed written and verbal information as to the nature of the injury and treatment including postoperative instruction Sedimentation rate and Hb-value were checked and blood grouping was done

The cause of injury was games or sports in 44 cases while 28 patients referred to some other cause, and 54 could not recall any trauma No difference existed in the distribution of traumatic and non-traumatic injuries between the two groups. Also concerning games and sports, the difference between the groups was insignificant (39 operated outpatients and 30 operated inpatients)

Those operated on as inpatients were admitted to the hospital the day before the operation for normal preoperative examination. They were usually discharged 1–3 days after the operation

Those to be operated on as outpatients reported to the operation department in the morning and there underwent a final preoperative appraisal by the operating surgeon After the operation, the patient was kept under observation for 4 to 6 hours and was allowed to leave the hospital after examination by the surgeon Only one of them asked to be admitted to the nursing department because of considerable pain in the operated knee

The majority of the patients in the two groups were operated on under epidural anaesthesia, the rest under general anaesthesia

Except for 14 who were followed up by another doctor, all patients were checked after the operation at our clinic, irrespective of whether they were treated as outpatients or inpatients.

Of the total number of cases, five outpatients and seven inpatients had a concomitant injury to the anterior cruciate ligament and 21 and 18 patients, respectively, showed signs of chondromalacia patellae Nothing was done about these conditions in connection with the operation

POSTOPERATIVE FOLLOW-UP

Thirty-two outpatients and 34 inpatients experienced the first days at home as troublesome Thus there was no difference between the two groups despite the fact that the inpatients had spent 1 to 3 days in hospital after the operation.

During their first days at home 32 outpatients and 25 inpatients needed help from members of their family, and 39 and 35, respectively took pain-relieving tablets. Thus there was no significant difference between the two groups in this respect either

When leaving hospital, the patients were given crutches and instructed to use them as long as they found it necessary, otherwise they were allowed unrestricted use of the knee Nineteen outpatients and 16 inpatients used the crutches for less than 5 days, and 50 and 46, respectively for less than 2 weeks

Of the 39 outpatients and 30 inpatients who took part in games and sports before the operation, 27 and 20 patients, respectively, continued to do so after operation The practice was usually resumed 7 to 12 weeks after the operation There was no difference between the two groups.

Table 2 shows the postoperative sick leave period There is no significant difference between the two groups Thus, 45 days after the operation, 39 outpatients and 42 inpatients were back at work The seven patients in each group who were on sick-leave for more than 76 days had apart from meniscus injury, also other changes in the knee joint, such as cruciate ligament injury or chondromalacia patellae

Table 3 shows the number of visits to the outpatient clinic after the operation Fourteen patients, however, were advised to report to their local doctor Patients who reported more than three times usually belonged to the group of multiple lesions and they had the longest period of incapacity to work

All patients were told that they should im-

Table 2 Postoperative sick leave period in days

Days	No of outpatients	No of inpatients
0–15	8	8
16–30	10	17
31–45	21	17
46–60	12	12
61–75	4	3
>76	7	7
No information	2	1

There are no significant differences between the two groups (Chi^2=2.35, d f =5, $P>50$ per cent)

Table 3 Number of postoperative visits

No of post-operative visits	No of outpatients	No of inpatients
0	6	8
1	27	27
2	21	16
3	5	6
4	1	2
5	2	4
6	2	2

There are no significant differences between the groups (Chi^2=2 35, d.f –5, $P>50$ per cent)

mediately visit the casualty department if they suffered any discomfort. During the first postoperative week, none of the inpatients and only three of the outpatients did so Two of the outpatients visited the casualty department because of minor discomfort, which required no medical treatment. A 27-year-old man operated as an outpatient called 7 days after the operation with a deep venous thrombosis in the lower leg This was treated successfully in the hospital with complete recovery None of the inpatients required readmission for an acute condition The case of deep thrombosis was the only postoperative complication in the entire series.

Only 31 patients in each group considered that they were completely recovered 6 months after the operation. Apart from a few exceptions those who did not consider themselves fully recovered thought that their condition did not justify a visit to the doctor The patients who were still being treated after 6 months belonged to the group with operative findings other than meniscus injury

DISCUSSION

A comparison of operated outpatients with operated inpatients shows that there are no significant differences between the groups as regards the postoperative course Both groups experience the first days at home as troublesome, and objective parameters, such as the period of incapacity to work and the number of visits to the outpatient clinic, show slight or no differences. The only postoperative complication, the case of deep lower leg thrombosis, has no connection with the outpatient surgical procedure as such. Most essentially the end result in the two groups is the same

When treating patients with meniscus injuries with outpatient surgery the crucial point is to secure a safe and relevant aftertreatment In our opinion this can be done only by a careful verbal and written communication which entails that the patient achieves a true understanding of what the lesion and the surgery is about and most important of all how he is to perform relevant training of his knee extensors without provoking an undue synovial irritation of the knee joint

All those who are to be operated on as outpatients should have the clinical diagnosis confirmed as an isolated meniscus injury, without concomitant lesions to the crucial ligaments. Usually these combined lesions produce instability symptoms and in such cases more detailed evaluation, either arthrography or arthroscopy, is needed The most benign and symptomless cases of anterior cruciate rupture found in the present series obviously do not need surgical treatment

The study shows that a considerable number of the patients need some help at home during the first days after the operation. It is therefore inadvisable to operate on as outpatients those who live alone and lack immediate help from another person

The advantage of meniscus operation as an outpatient procedure is perhaps the release of expensive nursing resources for others who require more nursing care Annually around

150 patients are operated for meniscus lesions at our clinic. Of these, almost half are operated as outpatients, i e, about 225 to 300 bed-days are released for other groups of patients. If we consider the patient's social situation, that is to say, whether or not he lives alone, we think that without increased discomfort for the patient and without increased medical risks it is possible to operate on a large group of patients with meniscus injury as outpatients.

REFERENCES

Helfet, A S (1963) *The management of internal derangements of the knee* J B Lippincott Co, Philadelphia

McGinty, J B, Geuss, L F & Marvin, R A (1977) Partial or total meniscectomy A comparative analysis. *J Bone Jt Surg* 59 A, 763–766

Smillie, I S (1962) *Injuries of the knee joint* 3rd ed., The Williams and Wilkins Co, Baltimore.

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IMMEDIATE EFFECTS OF MENISCECTOMY ON THE KNEE JOINT

The Effects of Tensile Load on Knee Joint Ligaments in Dogs

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Tensile strength variables for the collateral ligaments were compared after excision of the meniscus in one knee, the corresponding meniscus in the contralateral knee of the same dog being intact Removal of the meniscus was associated with a three fold [illegible] two fold for the [illegible]

not affected by lateral meniscectomy It is proposed that tensile loads are distributed more favourably in the medial collateral ligament by the intact medial meniscus with firm capsular attachments than in the "normal" ligament after meniscectomy

Key words knee joint, ligament articular, semilunar cartilage, tensile strength

Accepted 22 i 78

Many different functions have been attributed to the menisci of the knee joint. Smillie (1970) maintains that the menisci increase the stability of the joint "by deepening the tibial surface and filling in the dead space" Slocum & Larson (1968) describe rotatory instability of the knee joint, and state that the medial meniscus to some extent blocks this instability by virtue of the posterior horn volume Wang & Walker (1974) found experimental evidence of a rotatory stabilizing function of the menisci Fairbank (1948) also suggested a weight-bearing function Several others believe that the stability of the knee joint is impaired after medial meniscectomy (Smillie 1970, Johnson et al 1974, Kennedy et al 1974)

This study was designed to answer the following questions.

1 Do the menisci contribute to the stability of the knee joint?
2 If so, is the stabilizing effect due only to the volume and form of the menisci, or is it dependent on the close anatomical relationship between the meniscus and collateral ligament on the medial side and is consequently confined to this compartment?
3 Is the maximum load uptake of the medial collateral ligament affected by meniscectomy?

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MATERIAL AND METHODS

The study was performed on beagle dogs of average weight 11 7 kg (range 7 7–17 5) and mean age 12 months (range 11–13) They were bred at the same kennels, and were all in good condition at the time of killing Two different series were studied separately

Series A Twenty joints from 10 animals were used to compare the tensile strengths of the right and left medial collateral ligaments. Meniscectomy was not done on these joints, which had been frozen before the tests.

Series B (Figure 1) Another series of fresh samples was run to compare the tensile strength of one collateral ligament of one knee with that of the corresponding ligament of the other knee from the same animal, on the one side in the presence of the intact meniscus and on the other after removal of that structure The groups were selected at random This series comprised fresh knee joints from 40 dogs, the tests being ca out within 2–10 hours of killing During this all specimens were kept cool. The l deformation curves were analysed and the res treated statistically by the usual meth (Snedecor & Cochran 1967)

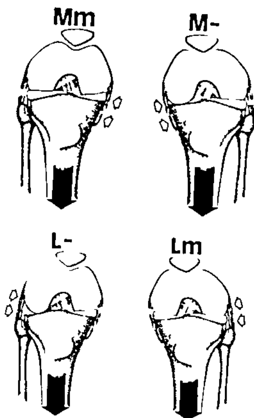


Figure 1 Tensile load applied to the medial or lateral collateral ligament in both *knees of the same animal All other capsular and ligamentous structures divided The corre... lateral) me... application ...*

Preparation of specimens

After killing, the hind legs were disarticulated the hip joints. The femur and tibia were fr from muscles without opening the knee capsule interfering with ligament structures The free en of the femur and tibia were placed in aluminiu cylinders. After centring, the bone was fixed position with Wood's metal type B at 58°C. T bone, Wood's ... joint and its capsular structures intact

Before dissection, the angle between the tube in full extension was measured for each specime to guarantee accurate positioning in the machine The fibres of the collateral ligament were the identified and dissected free Identification of the most anterior and most posterior fibres was facilitated by lateral angulation of the joint at different degrees of extension and flexion Two short incisions were made in the capsule at the anterior and posterior borders of the ligament parallel to the fibres (Figure 2) The purpose of this incision was to facilitate the following dissection after mounting (see below), eliminating accidental injury to the collateral ligament fibres. At this point (in series B) it was announced whether the joint was to be tested with the meniscus intact or excised Joints with intact ...

Removal of meniscus

An incision was made along the periphery of the meniscus starting at the anterior end of the cartilage, with the knee flexed 90° When the anterior and middle third had been separated from the capsule the meniscus was divided transversely (Figure 3) and the detached segment taken out. The posterior horn was thus left in place together with the intact posterior capsule, the collateral ligaments, and the cruciates while the specimen was being mounted in the machine These intact ligaments guaranteed correct anatomical positioning of the joint When the preparation had been rigidly mounted the cruciates, the posterior capsule and the collateral ligament not being

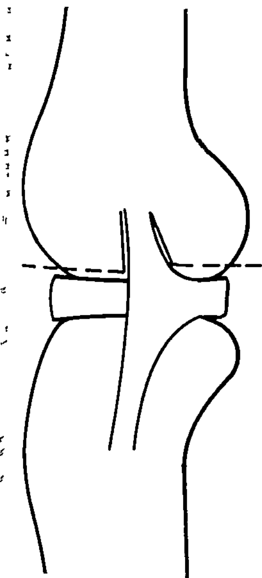


Figure 2 Incisions parallel to fibres of the collateral ligaments before mounting (—) and before excision of meniscus Incisions made after mounting (----)

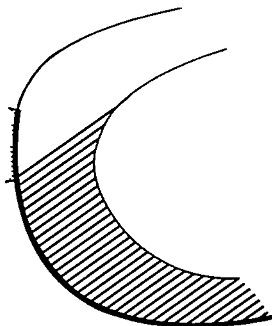


Figure 3 ▨ Meniscus segment excised before mounting (M-, L-) (▬) Meniscus and its attachment to the capsule divided □ Segment removed after mounting, before test

tested were divided With the posterior capsule wide open the posterior horn could then easily be cut out with the scalpel under full view The entire meniscus could thus be excised without risk of damage to the ligament to be tested

Equipment

A material testing system (MTS 5 Mp, MTS Corporation, Minneapolis, Minnesota, USA) with an error of ±1 per cent of the recorded load was used All tests were carried out at a deformation rate of 15 mm/s The deformation of the test structures was recorded with an inductive transducer built into the movable piston of the machine The load was registered as a function of the deformation on a Bryans 26000 xy-recorder (Bryans Southern Instruments Ltd, Mitcham, Surrey, England)

Symbols and definitions

Maximum load — maximum tensile load corrected for body weight (Pmax, N/kg b w, Figure 4)
Elasticity angle — the angle between the linear part of the curve and the horizontal axis (α, °)
Laxity — the distance on the load deformation diagram from zero to the point extrapolated from the linear part of the curve on the x-axis (δ_0, mm)
Elongation — the elastic and plastic phase of deformation projected on the x-axis (δ_1 mm)
Total elongation — the sum of laxity and elongation phase (mm)
Ligament – condyle distance — the distance from the tested ligament to the midpoint of the femorotibial contact area on the contralateral tibial condyle (MFTC) (c, mm)

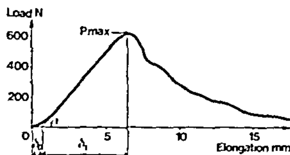


Figure 4 Characteristic load-deformation diagram for a ligament, showing three phases the initial laxity (the "toe"), the second phase of elastic deformation, and the third phase of plastic deformation.

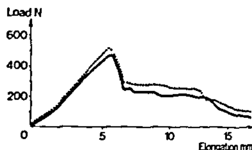


Figure 5 Load-deformation diagram of right ( ) and left (–) medial collateral ligaments from the same animal. An aberration is seen in the curve for the left ligament before breaking point Apart from this there is close agreement between the two sides before the rupture. The diagram also shows that continuity of the ligament is lost at a late stage and at great deformation

Laxity angle — the approximate angle (β) corresponding to the laxity phase when the vertical deformation movement is theoretically converted into an angulation in the transversal plane with an axis through MFTC. $\mathrm{Tg}\,\beta = \frac{\delta_0}{c}$

Rupture angle — the approximate angle (γ) corresponding to the total elongation of the ligament when the vertical deformation is theoretically converted into a transverse angulation with an axis through MFTC. $\mathrm{Tg}\,\gamma = \frac{\delta_0 + \delta_1}{c}$

RESULTS

Series A (n=20) The twenty controls showed a coefficient of variation between right and left legs of ±5 4 per cent with regard to *maximum load at rupture* of the medial collateral ligaments. The difference between right and left was not significant. Concerning *laxity*, the difference between right and left was not statistically significant, but *elongation* was significantly less on the right side than on the left ($P<0.02$) Small unexpected aberrations in the linear part of the curve were seen more often for the left ligament than for the right (Figure 5)

Series B (n=80) The following results were obtained Table 1 shows the *laxity* of the medial collateral ligament With the mensicus intact the values were higher at 30° flexion than with the knee extended ($P<0.02$) After excision of the mensicus (Group M-) the values were still higher, both in extension ($P<0.001$) and 30° flexion ($P<0.02$). The corresponding values for the lateral collateral ligament (Table 2) were also significantly higher ($P<0.001$) after excision of the lateral

Table 1 The laxity (δ_0, mm) of the medial collateral ligament with intact (Mm) and extirpated (M-) medial meniscus in different positions of the knee joint (mean±s.e.m.). All structures but the test ligament were divided in four dogs before fixation in the test machine and these figures were therefore excluded from this part of the study

Test position	Medial meniscus intact (Mm)	Medial meniscus extirpated (M-)	
extension ($n=11$)	0 26±0 17	0.75±0 29	$P<0.001$
flexion 30° ($n=14$)	0 50±0.28	0 75±0 25	$P<0.0?$
	$P<0.02$	n.s.	

Table 2 The laxity (δ_0, mm) of the lateral collateral ligament with intact (Lm) and extirpated lateral meniscus (L-) All tests were carried out on the extended joint.

Test position	Lateral meniscus intact (Lm)	Lateral meniscus extirpated (L-)	
extension ($n=11$)	0 31±0 19	0.54±0 21	$P<0.001$

Table 3 The maximum load (P_{max} N/kg body weight) for the medial (Mm, M- resp) and lateral (Lm, L- resp) collateral ligaments with intact and with extirpated meniscus

Tested ligament	Meniscus intact	Meniscus extirpated	
Medial coll. lig ($n=29$)	44 1 ± 10 7	38 8 ± 9 8	$P<0\ 001$
Lateral coll lig ($n=11$)	43 7 ± 6 8	43 9 ± 9 1	n s.

meniscus (Group L-) The *laxity* in Group M- was, however, significantly higher than in Group L- when tested in the same position ($P<0\ 05$) There was no significant difference in elongation of the collateral ligament between groups Mm and M- and Lm and L-, respectively (means for the medial collateral ligament 5 01 ± 0 80 in extension and 5 59 ± 0 68 in 30° flexion)

The Young modulus of elasticity for collagenous structures was not calculated owing to lack of precise methods for studying the cross-sectional area of the ligament (Ellis 1969)

The values for *maximum load* were lower after medial meniscectomy (see Table 3) The tests on the medial collateral ligament with intact meniscus showed a mean load at rupture of 44 1 ± 10 7 N/kg body weight, whereas the other knees from the same dogs showed a mean load at rupture of only 38 8 ± 9 8 N/kg body weight after excision of the medial meniscus. This difference is highly significant ($P<0\ 001$) Excision of the lateral meniscus caused no significant change in tensile strength of the lateral collateral ligament.

With the approximation that transverse angulation of the tibia occurs about an axis through the midpoint of the tibial condylar surface when this is under compression and not subject to sliding and rotation, the *laxity* and *rupture angles* were calculated from the following formulae

$$\mathrm{Tg}\,\beta = \frac{\delta_0}{c} \text{ and } \mathrm{Tg}\,\gamma = \frac{\delta_0 + \delta_1}{c}$$

The *mean laxity angle* increased in both groups after medial meniscectomy from 0 7° to 2 1°, and after lateral meniscectomy from 0 7° to 1 2°, when tested under extension The *rupture angle* showed no significant change after meniscectomy (medial mean 15 9°, and lateral mean 13 3°)

Localization of tear in ligament

Nearly 80 per cent of the tears on the medial side took place 1/2–1 cm below the condylar surface of the tibia, that is, where deep fibres of the ligament are inserted and the superficial fibres ride over the convex part of the tibial surface The other 20 per cent were situated at the proximal and distal insertions of the ligament Groups Mm and M- showed no observable difference concerning type or localization of the tear The lateral tears revealed a weak point just at the fibular insertion of the ligament, where most tears occurred

DISCUSSION

For practical and ethical reasons it is often impossible to obtain suitable human material Many biomechanical investigations have therefore been done on tendon and ligament preparations from rats, rabbits, cats, dogs, monkeys and other species (Smith 1954, Viidik & Lewin 1966, Matthews & Ellis 1968, Haut & Little 1969, Gupta et al. 1971, Welsh et al. 1971 and Noyes et al. 1974) The gross morphology of the knee joint with regard to menisci and cruciate and collateral ligaments is essentially similar in man and many breeds of dogs, and like some other researchers (Marshall & Olsson 1971, O'Donoghue et al. 1971, Alm et al. 1974) we therefore used dogs for this study Caution should be exercised, however, when applying these results to human conditions.

The increased laxity of the ligament after removal of a meniscus might suggest that the structure has in some way undergone change Laxity was increased not only for the medial collateral ligament after medial meniscectomy, however, the lateral collateral ligament

also showed increased laxity after lateral meniscectomy in spite of the known absence of anatomical relations between the meniscus and ligament in this compartment. This means, then, that resection of the anterior and middle two-thirds of the meniscus with all ligaments and practically all capsular structures intact leads to a slight but significant alteration in femoro-tibial orientation, which in turn implies that the menisci are normally under pre-stress when no external tension or compression is applied. Owing to their form and position the menisci will then come under further stress when the joint is compressed by weight-bearing. These changes in the initial part of the tension-load-deformation curve therefore corroborate the theory that the menisci have a weight-bearing function. Preliminary studies on load-deformation due to compression forces in human knee joints before and after meniscectomy have been published by Seedom et al. (1974), who found the part played by the meniscus in weight-bearing to be about 50 per cent. Using pressure transducers on cadaver knees Walker & Erkman (1975) also found the menisci to take up at least 50 per cent of the total load through the joint, more being taken up on the lateral side than the medial. Apart from the finding of normal meniscus pre-stress we are unable on the basis of our present findings to assess further the contribution of the menisci in weight-bearing. The pre-stress of the menisci reflected by our figures for *laxity* seems to vary with flexion and extension. Walker & Hajek (1972) studied the part played by the menisci in the contact stress on the central areas of the articular cartilage, and found reduction in contact stress especially at the extremes of motion. Our results correspond with this. However, laxity and pre-stress are affected by the mutual relations of the joint mechanics and ligament insertions in different positions of the joint.

As we have shown, meniscectomy may also lead to a three-fold increase in transverse angulation. An initial laxity of 2° might seem too small to be of any importance. Nevertheless, in a study on weight transmission through the human knee joint Kostuik et al. (1975) found that a lateral angulation of 3° in either direction completely disburdened the opposite condyle. Consequently, this apparently minor change after meniscectomy may have far-reaching mechanical consequences for the joint. Furthermore, experimentally induced instability of the knee joint in dogs is known to promote degenerative changes (Marshall & Olsson 1971, O'Donoghue et al. 1971), and such changes are seen also in man (Salter 1970). The increased laxity and alteration in femoro-tibial orientation we have found may help to explain the high incidence of degenerative changes in the human knee joint cartilage (Fairbank 1948, Tapper & Hoover 1969, Dandy & Jackson 1975) after meniscectomy.

The increase in laxity was greater after excision of the medial than the lateral meniscus, suggesting that factors other than mere loss of meniscus volume may be in operation on the medial side. Meniscectomy may possibly lead to unavoidable disturbance of the intimate relationship between the meniscus and the medial ligament complex. Surprisingly, the leaving behind of a small rim of meniscus in a few cases did not seem to influence the result. The effects of this anatomical relationship on the tensile properties of the ligament have not been investigated in man.

The maximum tensile strength also differed on the medial and lateral sides. As expected, meniscectomy did not affect the tensile properties of the lateral collateral ligament, but the maximum tensile strength of the medial ligament diminished by 12 per cent. A corresponding reduction in elongation might have been expected, but this was not significant. The tear [illegible] not at the level of the excised meniscus [illegible] stally, however Furthermore, al[illegible] rim remained th[illegible] am[illegible] stant than [illegible] would [illegible] reduced [illegible] after

meniscectomy Hypothetically, the stress over the tibial area, where most of the ruptures occurred, would appear to be better distributed under physiological conditions by the intact bonds between the medial meniscus and the ligament than after meniscectomy

The strength of the medial collateral ligament in dogs has also been studied by Tipton et al (1970) If their figures for separation force are corrected for mean body weight, the ligament in the trained group of dogs showed a mean strength of only 27 0 N/kg body weight, that is, much lower than in this study The material differed, however, and furthermore the deformation rate was only 0 25 mm/s Collagenous tissue shows a strain rate sensitivity At high rates of deformation, tissue elasticity is changed, collagenous tissue tolerates a greater load before rupture, and the incidence of ligamentous tears will exceed the incidence of bone avulsion (Noyes et al 1974) Our findings consequently seem more physiological

Elongation was the only factor that showed a significant difference between right and left This is not accompanied by a significant change in stiffness (tan α) between the compared ligaments, however The difference seemed instead to be due to small aberrations in the curve, commoner in the left-side preparations than in the right It cannot be determined whether these changes in deformation of the bone-ligament-bone preparation occur within the ligament substance or at the insertions. It seems quite possible that the aberrations could represent tears of isolated fibre bundles before ligament failure occurs, and in fact such microscopical breaches preceding ultimate disruption have been described (Noyes et al 1974) Differences in tensile properties and elasticity of bone-ligament bone preparations between trained and untrained limbs have also been reported (Viidik 1968, Laros et al 1971) Viidik (1968) felt that qualitative changes must take place within the ligamentous tissues owing to differences in the load-relaxation phenomenon Our findings may indicate that there is some qualitative difference in the medial collateral ligaments on the dominant and non-dominant sides.

Summary and conclusions

The knee joint of beagle dogs, which bears essential similarities to the human knee joint, showed the following changes after excision of the medial or lateral meniscus.

1 Removal of a medial or lateral meniscus leads to a small but significant change in the laxity of the joint The results indicate that the menisci are normally under prestress.
2 The increase in laxity angle is nearly two-fold after removal of the lateral meniscus and three-fold after removal of the medial the greater increase after medial meniscectomy possibly being due to disturbance of the intimate anatomical relationship between the medial meniscus and the deep capsular fibres of the medial collateral ligament
3 The medial collateral ligament shows a reduction of load at failure of more than 10 per cent *immediately* after meniscectomy
4 The results accord with previous compression load investigations, indicating that the meniscus may have a load-bearing function With this experimental model, however, the magnitude of this function cannot be studied

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REFERENCES

Alm A. Ekstrom, H & Stromberg B (1974) Tensile strength of the anterior cruciate ligament in the dog *Acta chir scand.*, Suppl. 445 15–23

Acta orthop scand. 49, 415–419, 1978

EFFECT OF PNEUMATIC TOURNIQUET ON MUSCLE OXYGEN TENSION

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Recent investigations suggest that circulation in a limb can be reduced with a tourniquet to less than 1 per cent of the control limb, or even completely occluded The development of tissue oxygen tonometry with implanted silastic tubes has provided new possibilities for assessing muscle tissue oxygen tension In the present work, this method was employed to register the effect of tourniquet blockade on the lower limb muscle PO_2 in rabbits The duration of the tourniquet blockade was 60, 120 and 180 minutes. The baseline muscle PO_2 in the tibialis anterior muscle was 22.6 ± 0.6 mmHg During the tourniquet blockade the oxygen tension dropped to minimal values between 9.2 ± 0.5 and 10.7 ± 0.6 mmHg in these experimental groups, but the tissue microclimate never reached fully anoxic conditions. The rapid response of muscle PO_2 to oxygen breathing after release of the blockade suggests that limb microcirculation tolerates tourniquet occlusion well

Key words pneumatic tourniquet, tissue PO_2, silastic tonometer

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The clinical advantages of a pneumatic tourniquet are well known, since surgery in a bloodless field has been practised for over a century (Esmarch 1873) However, maintaining tourniquet blockade involves disadvantages, the greatest of which is probably tissue ischaemia

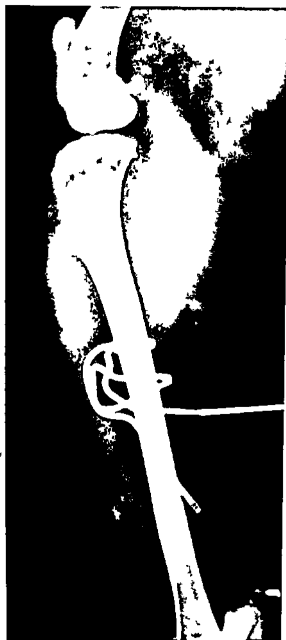
Recent investigations suggest that circulation in a limb can be reduced with a tourniquet to less than 1 per cent of the control limb (Klenerman & Crawley 1977) The resistance of the microcirculation of striated muscle against ischaemia is largely unknown In recent studies the role of tissue oxygenation in operative procedures has been emphasized (Kivisaari & Niinikoski 1975, Niinikoski 1977).

The development of tissue oxygen tonometry with implanted silastic tubes (Niinikoski & Hunt 1972) has provided new possibilities for investigating muscle tissue oxygen tension In the present work, this method was employed to register the effect of tourniquet blockade on the lower limb muscle PO_2 in rabbits

MATERIAL AND METHODS

Seventeen rabbits of both sexes, weight 3.0–3.9 kg, were used in this study Anaesthesia was induced with intravenous sodium pentobar-
[illegible]
(Holter® Atrial Catheter J, A 190, Extracorporeal

Medical Specialties Inc., Millis, Mass., USA) was implanted in the tibialis anterior muscle (Figure 1). The implantation was made through a wide-bore needle. The tube ends were left outside the skin after closure and fixed with a silk ligature. A length of 14 to 15 cm remained inside the muscle tissue. Three days later the rabbit was again anaesthetized and muscle oxygen tension



was determined according to Niinikoski & Hunt (1972). The silastic tonometer was perfused continuously with hypoxic saline PO_2 3 to 8 mmHg with a slow injection pump (Model 1100 Harvard Apparatus Co. Inc., Millis, Mass. USA), and tissue PO_2 was measured from the efflux in the Radiometer gas monitor coupled with a Servogor[3] chart recorder (Goerz Electro GmbH Vienna, Austria). Oxygen impermeable nylon catheters were used as connector tubes in the perfusion system. The response of different durations of tourniquet blockade was measured. Five rabbits had 60-minute tourniquet ischaemia and in five animals ischaemia lasted for 120 or 180 minutes, respectively. The tourniquet ischaemia was maintained by means of a 6 cm broad, Riva Rocci type cuff around the upper part of the leg. The cuff was inflated to 300 mmHg. In each animal the response of the muscle oxygen tension to the release of tourniquet and to breathing of pure oxygen was also registered. In two cases the tourniquet blockade lasted 30 minutes and breathing of pure oxygen was continued throughout the whole experiment.

RESULTS

The baseline PO_2 before the application of the pneumatic tourniquet ranged between 18 and 26 mmHg (mean and SEM 22.6 ± 0.6 mmHg). Breathing of pure oxygen for a period of 15 minutes increased the level of intramuscular PO_2 to 90–130 mmHg.

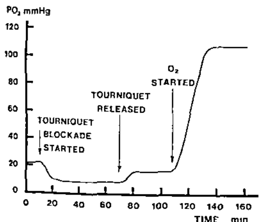
During 60 minutes of tourniquet ischaemia the intramuscular PO_2 declined from the baseline value of 22.2 ± 1.2 mmHg to a minimal value of 9.3 ± 0.6 mmHg within 20–24 minutes (Figure 2a). After release of the tourniquet the PO_2 reached a stable value of 17.8 ± 0.8 mmHg in 5 to 10 minutes and then remained unchanged during the following 30 minutes. When the PO_2 had been stabilized, the rabbits were exposed to pure oxygen through a head tent. This resulted in an intramuscular PO_2 of 85–130 mmHg within 15 to 20 minutes.

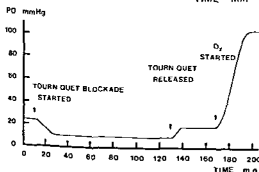
During 120 minutes of tourniquet ischaemia the PO_2 declined from the baseline value of 23.7 ± 1.1 mmHg to a minimal value of 10.7 ± 0.6 mmHg within 22 to 28 minutes (Figure 2b). In 5 to 10 minutes after release of the tourniquet, the PO_2 reached a stable level

of 19 5 ± 0 8 mmHg The intramuscular PO_2 responded in all cases to oxygen breathing with an increase to 80–120 mmHg

During 180 minutes of tourniquet ischaemia the PO_2 declined from the baseline value of 21 7 ± 1 1 mmHg to a minimal value of 9 2 ± 0 5 mmHg within 19–26 minutes (Figure 2c) After releasing the tourniquet, the PO_2 reached a stable level of 17 0 ± 0 5 mmHg in 10–17 minutes The response to pure oxygen breathing was an increase of the intramuscular PO_2 to 90–115 mmHg

When pure oxygen breathing was continued throughout the experiment, a decline of the PO_2 from 120 mmHg to 11 mmHg was registered (Figure 3)





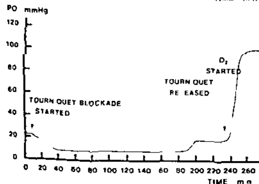


Figure 2 (a) Effect of 60 minute tourniquet blockade on muscle PO_2 (b) Effect of 120-minute tourniquet blockade on muscle PO_2 (c) Effect of 180-minute blockade on muscle PO_2.

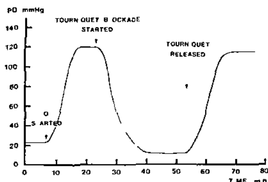


Figure 3 Effect of pure oxygen breathing continued throughout the experiment A decline of the PO_2 from 120 mmHg to 11 mmHg was registered

DISCUSSION

The silastic tonometer method of measuring tissue oxygen tension is already well established and has showed its usefulness in several studies Niinikoski et al. (1972) showed that the silastic tube induces a minimal foreign body reaction

Kivisaari & Niinikoski (1973) concluded that one of the main problems involved in measuring tissue gases by means of microelectrodes is the wide topographical variation of the PO_2 readings that normally occurs (Silver 1969) The advantage of the silastic tonometer is that it measures the average extracellular tissue PO_2 (Niinikoski & Hunt 1972)

In earlier investigations the silastic tonometer has been used extensively in several tissues, such as human subcutaneous tissue (Niinikoski et al. 1972, Kivisaari & Niinikoski 1973, Heppenstall et al 1974) human muscle (Cooke et al 1974), intestinal

wall and peritoneal cavity in animals (Inberg et al 1974, Klossner et al 1974), canine lung (Havia & Niinikoski 1976) and canine heart (Havia & Niinikoski 1977)

The *reported mean baseline* PO_2 *values* have varied in most tissues between 20 and 30 mmHg In rabbit subcutaneous tissue PO_2 varied between 20 and 25 mmHg (Niinikoski & Hunt 1972) Canine myocardium PO_2 ranged from as low as 8 to 40 mmHg with a mean of 22 mmHg

The baseline muscle PO_2 ranged in our study from 18 to 26 mmHg This is compatible with the tissue oxygen tensions reported in other studies

In the present study, the application of tourniquet always produced a decline in the intramuscular oxygen tension The minimal value of 9–11 mmHg was achieved in 19–26 minutes and then remained constant during the rest of the tourniquet time, but never reached zero In accordance with the present findings, Niinikoski et al (1972) found it puzzling that a 20-minute occlusion of limb circulation did not result in a PO_2 of zero in human subcutaneous tissue In the investigation of Kivisaari & Niinikoski (1975) the intraosseous PO_2 fell abruptly after circulatory arrest so that most of the decrease occurred within 2 minutes, but also in this case the PO_2 never reached zero Furthermore, the release of circulation resulted momentarily in a PO_2 slightly above the normal level, probably due to reactive hyperaemia (Niinikoski et al 1972, Kivisaari & Niinikoski 1975) In the present study, the muscle PO_2 remained slightly under the normal level after releasing the blockade However, after a few minutes of pure oxygen breathing the PO_2 increased sharply This indicates that the microcirculation even after 3 hours of tourniquet *blockade was functioning* well

Continuous oxygen breathing during the tourniquet experiment had no influence on the decrease of the PO_2 and the minimal value was compatible with the one achieved with room air breathing This has been interpreted as total occlusion of the circulation caused by the tourniquet The decline of PO_2 and recovery after tourniquet release seemed to be independent of tourniquet time

It can be concluded that inducing a total *blockade of local circulation in an extremity* produces a profound fall of the muscle PO_2, but the tissue microclimate never reaches fully anoxic conditions. The rapid response of muscle PO_2 to oxygen breathing after release of the blockade suggests that tissue oxygenation is rapidly restored after tourniquet release

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REFERENCES

Cooke, P Heppenstall R Littooy F Hunt, T K & Wylie E (1974) The tissue oxygen tension as an index of collateral blood flow during acute arterial blood occlusion *S Afr J Surg* 12 91–99

Esmarch J (1873) Ueber kuenstliche Blutleere bei Operationen Sammlung klinischer Vortrage im Verbindung mit deutschen Klinikern. *Chirurgie* 19 373–383

Havia T & Niinikoski J (1977) Intramyocardial gas tensions in the canine heart *Scand J thorac cardiovasc Surg* 11 89–96

Havia T & Niinikoski J (1976) Parenchymal gas tensions in canine lung *Scand J thorac cardiovasc Surg* 10 243–246

Heppenstall, R Littooy, F Fuchs, R Sheldon, G & Hunt T K. (1974) Gas tensions in healing tissues in traumatized patients. *Surgery* 75 874–880

Inberg *M*, *Havia T* Arola M & Niinikoski, J (1974) Effect of oxygen breathing on jejunal tissue gas tensions during superior mesenteric arterial occlusion *Scand J Gastroent* 9 337–342

Kivisaari J & Niinikoski J (1973) Use of silastic tube and capillary sampling technic in the measurement of tissue PO_2 and PCO_2. *Amer J Surg* 125 623–627

Kivisaari, J & Niinikoski, J (1975) Tissue oxygen and carbon dioxide tensions in healing rabbit tibias. *Acta orthop scand* 46, 269–279
Klenerman, L & Crawley, J (1977) Limb blood flow in the presence of a tourniquet *Acta orthop scand* 48, 291–295
Klossner, J, Kivisaari J & Niinikoski, J (1974) Oxygen and carbon dioxide tensions in the abdominal cavity and colonic wall of the rabbit. *Amer J Surg* **127**, 711–715
Niinikoski, J & Hunt, T K (1972) Measurement of wound oxygen with implanted silastic tubes *Surgery* **71**, 22–26
Niinikoski, J, Heughan, C & Hunt, T K. (1972) Oxygen tensions in human wounds *J Surg Res* **12**, 77–82
Niinikoski, J (1977) Oxygen and wound healing *J Clin Plast Surg* **4**, 361–374
Silver, I (1969) The measurement of oxygen tension in healing tissue *Progr Resp Res* **3**, 124–135

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THE INFLUENCE OF THE DEEP FEMORAL ARTERY ON WOUND HEALING IN AMPUTEES

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Seventeen patients with arterial occlusive disease, of whom 14 were diabetics, were studied by angiography after amputation of the lower ex[illegible] [illegible] alone was occluded and wound healing was normal and in nine patien[illegible] both the superficial and deep femoral arteries were occluded and wou[illegible] healing was delayed

Wound healing of the stump after amputation of the lower extremity d[illegible] to extensive arterial occlusive disease is decided by the patency of the de[illegible] femoral artery

Key words amputation angiography, arterial occlusive disease, de[illegible] femoral artery, superficial femoral artery, wound healing

Accepted 28 iii 78

Level of amputation and quality of wound healing are of crucial importance in the rehabilitation of patients after amputation of the lower extremity for arterial occlusive disease Angiography is one of the tools used to determine the proper level of amputation (Baddeley & Fulford 1964) A successful amputation is considered one at "the lowest site with considerable chance of healing" (Browse 1973) It is important to determine the correlation between the angiographic findings and wound healing after amputation

PATIENTS AND METHODS

Angiographic investigations were carried out on 11 patients with lower extremity amputation for arterial occlusive disease, in whom the wound took more than 6 weeks to heal Six amputees with a normal rate of wound healing (within 6 weeks) were also investigated for compariso[illegible] All patients gave informed consent The age ran[illegible] was 60–89 years, all but one were men Fourte[illegible] were overt diabetics

The vessels investigated were

1 The trunk consisting of the common ilia[illegible] external iliac and common femoral arteri[illegible]
2 Superficial femoral artery
3 Deep femoral artery

Occlusion was graded as Absent or mild whe[illegible] [illegible] two of the authors without knowledge [illegible] patients' clinical findings. Angiography wa[illegible] performed by Seldinger's technique (1953)

RESULTS

Figure 1 represents a case where the whole arterial trunk of the lower limb is patent In Figure 2 the superficial femoral artery is com



Figure 1 Arteriography showing patent superficial and deep femoral arteries Figure 2 Arteriography showing occlusion of the superficial femoral artery and patent deep femoral artery Figure 3 Arteriography showing occlusion of the common femoral artery There is no filling of the superficial and deep femoral arteries

pletely occluded The deep femoral artery is patent and its network of collaterals can be seen In Figure 3 the main arterial trunk of the lower extremity is completely occluded

Table 1 presents the relation between rate of wound healing, the level of amputation and the artery occluded In one case no occlusion was demonstrated The reason for amputation in this case was occlusion in the arteries of the calf, and a successful below knee amputation was performed

In two cases none of the arteries of the lower extremity could be demonstrated on angiography This severe impairment of blood supply caused very prolonged wound healing of the stump (up to a year) In five cases the superficial femoral artery alone was occluded, and in nine cases both the superficial and the deep femoral arteries were occluded When only the superficial femoral artery was occluded, wound healing was normal, but when both the superficial and the deep femoral arteries were occluded, wound healing was delayed There was no difference between the above knee and the below knee amputations.

DISCUSSION

The superficial femoral artery conducts the blood supply for the calf and foot and it is the most frequent site of occlusion in arterial occlusive disease

Table 1 Site of arterial insufficiency, rate of wound healing and level of amputation

Site of arterial insufficiency	No of patients divided according to rate of wound healing and level of amputation				Total
	Delayed		Normal		
	AK	BK	AK	BK	
None				1	1
Common iliac, external iliac, common femoral, superficial femoral, deep femoral	2				2
Superficial femoral			2	3	5
Superficial femoral, deep femoral	6	3			9
Total	8	3	2	4	17

The deep femoral artery arises from the lateral aspect of the common femoral artery, supplies the thigh (Martin et al 1968) and anastomoses with branches of the popliteal and geniculate arteries (Boileau Grant 1958) It was believed that the deep femoral artery was only rarely affected in peripheral vascular disease Lindbom (1950) found that it was occluded in 4 out of 108 angiograms performed In later studies, narrowing a' the origin of the deep femoral artery w found in up to 39 per cent (Beales et al 1 with a higher incidence in diabetics (30 5 . cent) than in non-diabetics (9 5 per ... (Haimovici 1967, Tingaud et al 1974) T' findings are in agreement with those of our study and previous studies in Israel, all of which included a high proportion of diabetics (Gaspar 1968, Najenson & Levy 1972)

In the above-mentioned reports, as in the present study, occlusion of the deep femoral artery was part of an extensive arterial occlusive pattern and not an isolated lesion Healing after amputation was delayed when both the superficial and deep femoral arteries were occluded, but it was normal when the deep femoral artery was patent

It is our conclusion that the postoperative patency of the deep femoral artery is a major factor in the prognosis of an amputation at any level In the presence of superficial femoral artery occlusion, the patency of the deep femoral artery decides the outcome of a below knee amputation a ... source of the collaterals to the ... action as an artery of supply ... it also ... the ... knee

... deep ... role and ... by ... artery have ... & ... re- ... 76) who ... of ... are

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Beales, J S M., Adcock, F A., Frawley, J S, Nathan, B E., McLachlan, M S F, Martin, P & Steiner, R E. (1971) The radiological assessment of disease of the profunda femoris artery *Brit J Radiol* 44, 854–859

Boileau Grant, J C. (1958) *A method of anatomy*, 6th ed. p 394 The Williams & Wilkins Company, Baltimore

Browse N L (1973) Choice of level of amputation in ischemic arterial disease *Scand J clin Lab Invest*, Suppl. 128 249–252

Gaspar, E (1968) Rehabilitation of elderly amputees. *Harefuah* 75, 234

Haimovici, H (1967) Patterns of arteriosclerotic lesions of the lower extremity *Arch Surg* 95, 918–933

Lindbom, A. (1950) Arteriosclerosis and arterial thrombosis in the lower limb A roentgenological study *Acta radiol (Stockh)* Suppl 80, 1–80

Martin, P, Renwick, S & Stephenson, D (1968) On the surgery of the profunda femoris artery *Brit J Surg* 55, 539–542

Najenson, T & Levy, M (1972) Rehabilitation of amputees with progressive vascular disease *Rheum. Phys Med* 11, 250–259

Okike, N & Bernatz, P E (1976) The role of the deep femoral artery in revascularization of the lower extremity *Mayo Clin Proc* 51, 209–215

Seldinger, S I (1953) Catheter replacement of the needle in percutaneous arteriography A new technique *Acta radiol (Stockh)* 39, 368–376

Tingaud, R., Masse, C, Boissieras, P, Baste, J C & Plangol, P H (1974) Diabetic arteriopathies. *J cardiovasc Surg (Torino)* 15, 54–61

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It is our conclusion that the postoperative patency of the deep femoral artery is a major factor in the prognosis of an amputation at any level In the presence of superficial femoral artery occlusion, the patency of the deep femoral artery decides the outcome of a below knee amputation as it is the source of the collaterals to the calf and by its action as an artery of supply to the thigh, it also decides the prognosis of an above knee amputation

The role and importance of the deep femoral artery have been recognized by several surgeons (Martin et al 1968 Okike & Bernatz 1976) who have used it for revascularization of the lower extremity when other procedures are not possible

When an amputation wound fails to heal it is worthwhile performing an arteriography If the superficial femoral artery is found to be occluded the deep femoral artery should be studied with special care

REFERENCES

Baddeley, R R & Fulford J C (1964) The use of arteriography in conservative amputations for lesions of the feet in diabetes mellitus. *Brit J Surg* 51 658–663

MATERIAL AND METHODS

The material consisted of 62 full-grown rabbits with roentgenologically closed epiphyseal lines in the femur and the tibia The animals were [illegible]

groups according to the operation performed (Table 1).

Group 1 (40 animals) All cartilage in the patella groove of the femur in the right knee joint was excised, care being taken not to traumatize the subchondral bone In the left knee joint, used as a control, only arthrotomy was done After the operation, the incisions were closed by supramide sutures in the capsule and the skin

Group 2 (10 animals) The right and the left knee joints were treated in the same way as the right knee of the animals of group 1, i e, by total excision of the cartilage in the patella groove of the femur The difference between the two operated knee joints lay in the different times elapsing between operation and sacrifice.

Group 3 (12 animals) All cartilage in the intercondylar groove in the right knee joints was excised In the left knee joints one third of the cartilage in the groove was excised

The sutures were removed 1 week after the operation, except for the animals sacrificed 2 4 and 5 days after the operation, where the sutures were left intact. None of the animals showed signs of effusion, and the animals were able to use their operated legs on the day after the operation.

^{3}H thymidine was injected intra articularly in both joints 30 and 6 hours before sacrifice All animals were killed by an i v overdose of Nembutal® (Abbott) Immediately after death, articular cartilage from the tibial condyles and from the lateral femoral condyle of both knee joints was dissected in separate portions, care being taken to avoid the inclusion of subchondral bone and other tissues The material was weighed [illegible]

precipitate was washed three times, each time with 5 ml of TCA The insoluble residue was treated with 5 ml of 0 3 M potassium hydroxide for 18 hours at 37°C to hydrolyze RNA, which was thereby brought into solution. The solution was adjusted to pH 7 by the addition of 70 per cent perchloric acid Five ml of 5 per cent TCA

Table 1 Summary of the operations performed on the 62 rabbits and the days of sacrifice

		Operation performed	Days postoperatively*					
			2 days	4 days	5 days	8 days	10 days	14 days
Group 1 40 animals	Right knee joint	Excision of all cartilage of the patellar groove of the femur	10		10		10	10
	Left knee joint	Arthrotomy	10		10		10	10
Group 2 10 animals	Right knee joint	Excision of all cartilage of the patellar groove of the femur				10		
	Left knee joint	,,		10				
Group 3 12 animals	Right knee joint	Excision of all cartilage of the patellar groove of the femur						12
	Left knee joint	Excision of ⅓ of the cartilage of the patellar groove of the femur						12

* The figures in the Table refer to the number of animals sacrificed on the given days.

was added to the neutral solution This resulted in a precipitation of protein and DNA, which were separated from the solution by centrifugation and washing of the precipitate three times, each time with 5 ml of 5 per cent TCA. RNA and DNA in the separated fractions were determined with the orcinol reaction (Mejbaum 1939) and the Ceriotti procedure (Ceriotti 1952) respectively The separation of RNA and DNA was checked in all experiments by applying both reactions to the RNA as well as to the DNA fractions. The patella and the medial femoral condyle were used for histological and autoradiographical examination and were immediately fixed in 10 per cent formalin With a circular saw the patella was divided in the frontal plane, and the medial femoral condyle in the sagittal and transverse planes. The specimens were then decalcified in formic acid and sodium citrate, embedded in paraffin and cut into sections 5–7 µ thick The sections were stained with haematoxylin-eosin and according to the van Gieson method Autoradiographs of routine histological sections were prepared according to the dipping method with Ilford K2 liquid emulsion. After 3 weeks exposure, the autoradiograms were developed in Gevaert X-ray developer G 230 and fixed in Gevaert X-ray fixer G 305 The sections were stained through the emulsion with Mayer's haematoxylin

RESULTS

Biochemical study

There were no differences in DNA and RNA concentrations or DNA synthesis between the arthrotomized animals and the animals with joint cartilage partly or totally excised from the patellar groove

Histological study

Histological examination of the specimens revealed no persistent epiphyseal lines Well defined "tidemarks" could be seen In one of the specimens, where the cartilage had been excised from the patellar groove, the calcified cartilage had been damaged The cartilage was usually excised down to the lower part of the columnar layer

Control animals No changes from the normal were seen in the histological examination

Group 1

Two days after the operation – 10 animals Proliferation of synovial cells occurred at the joint margins and in one specimen osteoblastic activity was also seen The joint cartilage in three specimens showed chondrocytes, which appeared swollen in comparison with normal cells. In two of the above-mentioned specimens, small areas of cell necrosis were seen in the transitional and columnar layers of the cartilage In seven specimens no changes in the cartilage were seen, and there was no osteophyte formation in this group of animals

Five days after the operation – 10 animals The degree of cell proliferation at the joint margins was greater than after 2 days in all 10 animals Osteoblastic proliferation at the joint margins was seen in six animals In one of the animals, fibrillation was seen down to the "tidemark" in the cartilage of the patella and in the neighbourhood of this fibrillation, cluster formation was seen. The changes were located at the margins of the patella.

Ten days after the operation – 10 animals Proliferation of synovial cells at the joint margins was conspicuous. At the same site osteoblastic activity could be seen In three animals, osteophyte formation had started adjacent to the medial collateral ligament. Cluster formation was present in four animals, at the periphery of the patellar cartilage in three and in the femoral condyle in the fourth Clusters were seen in the superficial and transitional layers. However no greater signs of degeneration were seen, although sometimes the chondrocytes appeared swollen in comparison with normal cells, and in two of the patellas initial fibrillation was seen

Fourteen days after the operation – 10 animals The synovial cell proliferation and the osteoblastic activity were even more pronounced than after 10 days In one section the osteoblasts were not only seen at the margins

but also subchondrally under the whole joint cartilage. In 6 animals, osteophytes were seen adjacent to the medial collateral ligament Degenerative changes of the cartilage were not pronounced but in three animals chondrocytes appeared to be swollen, and in two animals fibrillation and flaking as well as local necrosis of the chondrocytes were seen in the patella sections

Group 2

These 10 animals presented changes similar to those seen in *group 1* as regards proliferation of synovial cells and osteoblastic activity No degenerative changes of the cartilage were seen and osteophytes were absent.

Group 3

The 12 animals in this group presented changes in their right knee joints similar to those seen in *group 1* 14 days postoperatively, i.e. peripheral proliferation of synovial cells and osteoblastic cell activity In one of the 12 animals fibrillation in the patella was suspected, and in three animals cluster formation in the superficial and transitional layers was present In the operated left knee joint only slight changes, consisting of synovial and osteoblastic proliferation, could be seen.

Autoradiographic findings

Group 1 – 10 animals Several autoradiograms (range 5–16) of each knee joint were studied. Labelled chondrocytes were occasionally seen in 8 out of 39 control knee joints (1 control was lost). The number of labelled cells ranged from 1 to 11 The section showing 11 labelled cells presented histologically a "tumour-like" growth of the cartilage, all the labelled cells being located in this formation. In the right knee joints, labelled chondrocytes were seen in two animals 2 days after the operation, in six animals 5 days after the operation, in eight animals 10 days after the operation, and in eight animals 14 days after the operation The labelled chondrocytes were seen in the patella as well as in the femur, and they were not only present around the operative defects of the cartilage The labelled chondrocytes were usually situated in the superficial and transitional layers whereas occasionally labelled cells were present in the columnar layer

Group 2 – 10 animals Four animals showed labelled chondrocytes 4 days after the operation, and six animals showed labelling 8 days after the operation. In only one of the left knee joints did the number of chondrocytes exceed that of the right knee joints.

Group 3 – 12 animals Eight animals showed labelling in the right knee joint and eight in the left knee joint No tendency towards a greater number of labelled chondrocytes was seen in the right knee joints, which had the more extensive operation.

In summarizing the autoradiographic findings, the following results are obtained, expressed in terms of labelled cells in relation to the number of histological sections

2 days	index	0 07
4 „	„	0 1
5 „	„	0 3
8 „	„	0 24
10 „	„	0 8
14 „	„	1 1

DISCUSSION

With the formation of a well-defined zone of calcified cartilage, the chondrocytes cease to divide. Mitotic figures have never been demonstrated in normal adult joint cartilage (Elliot 1936, Crelin & Southwick 1960, 1964 Mankin 1963, 1964, 1968, Telhag 1972) When degenerative changes appear the chondrocytes recover their ability to divide (Hulth et al. 1972) and the proliferation of chondrocytes can be estimated through the increased formation of DNA At the same

time the synthesis of RNA diminishes (Gudmundson & Telhag 1972) In an earlier investigation it was shown that sham operations on knee joints do not result in mitosis of the chondrocytes (Telhag 1972)

The presence of specific growth-inhibiting factors, "chalones", in tissues other than cartilage has been demonstrated by many investigators (Finegold 1965, Bullough & Laurence 1960, Moorhead et al 1969, Hennings et al 1969, Lasalvia et al 1970, Houck & Hennings 1973) In an earlier investigation (Havdrup et al 1975), it was shown that scattered mitosis of chondrocytes appeared in adult joint cartilage after localized traumatization

In the present investigation, it was not possible to demonstrate any changes in the biochemistry of the cartilage either in relation to the time elapsing after the operation or in relation to the degree of trauma This perhaps may be explained by the fact that the number of labelled chondrocytes is very low in relation to the total number of chondrocytes, and that the changes in the metabolism do not result in detectable changes in chemistry

Fairly abundant numbers of labelled chondrocytes were seen scattered in the right knee joints of the animals in group 1 and in both knee joints of the animals in groups 2 and 3 The number of ^{3}H-thymidine labelled chondrocytes showed a rising tendency up to 14 days postoperatively No peak value of mitosis was seen With increasing time postoperatively, the signs of synovial cell proliferation, osteoblastic activity and degeneration of cartilage developed slightly, but nothing is known about the eventual progress of the changes to manifest osteoarthritis In the present study, it was not possible to detect any difference between a smaller and a larger trauma in relation to the number of ^{3}H-thymidine labelled cells

In a paper concerning scattered mitosis of adult joint cartilage after a localized trauma, Havdrup et al (1975) showed that labelled chondrocytes could be seen in the sham operated knee joints In the present investigation, 8 out of 39 control knee joints in group 1 showed chondrocytes labelled by ^{3}H thymidine As mentioned previously, cell proliferation in other organs is regulated by specific cell inhibitors, i e, chalones When for example, liver and kidney (Saetren 1956) skin (Bullough & Laurence 1960 Finegold 1965) and bone marrow (Hulth & Johnell 1976) are damaged the remaining cells start dividing This is possibly due to a decreasing concentration of chalones In the present investigation a similar explanation can be given, i e, by excision of the cartilage the concentration of chalones in the operated knee joint is reduced and consequently the chondrocytes start dividing Possibly, the ^{3}H thymidine labelling of the chondrocytes of the control knee joints is due to a decrease in the concentration of circulating chalones If this is valid, mitosis of the chondrocytes in other joints should also appear

The explanation given above cannot be proven at present However, there is nothing to contradict the theory that chalones regulate the proliferation of chondrocytes. This could explain the initial regeneration of chondrocytes in osteoarthritis.

REFERENCES

Bullough W S & Laurence E B (1960) The control of epidermal mitotic activity in the mouse *Proc roy Soc B* **151** 517–536

Ceriotti G (1952) A microchemical determination of desoxyribonucleic acid *J biol Chem* **198** 297–303

Crelin E S & Sosthwick, W O (1960) Mitosis of chondrocytes induced in the knee joint articular cartilage of adult rabbits. *Yale J Biol Med* **33** 243–244

Crelin, E S & Southwick W O (1964) Changes induced by sustained pressure in the knee joint articular cartilage of adult rabbits *Anat Rec* **149**, 113–133

DePalma A F, McKeever C D & Subin D K (1966) Process of repair of articular cartilage demonstrated by histology and autoradiography with tritiated thymidine *Clin Orthop* **48**, 229–242

Elliot, H C (1936) Studies on articular cartilage I Growth mechanisms *Amer J Anat* **58** 127–140

Finegold, M J (1965) Control of cell multiplication in epidermis. *Proc Soc exp Biol (N Y)* 119 96–100

Gudmunson, C. & Telhag, H (1972) Nucleic acids in degenerative joint disease *Clin Orthop* **88**, 247–251

Havdrup, T, Hulth, A. & Telhag, H (1975) Scattered mitosis in mature joint cartilage in rabbits after local trauma *Clin Orthop* **113**, 246–248

Hennings, H, Elgjo, K & Iversen, O H (1969) Delayed inhibition of epidermal DNA synthesis after injection of an aqueous skin extract *Virchows Arch path Anat* **4**, 45–53

Houck, J C & Hennings, H (1973) Chalones, specific endogenous mitotic inhibitors. *FEBS Lett* **32**, 1–8

Hulth, A., Lindberg, L & Telhag, H (1972) Mitosis in human osteoarthritic cartilage *Clin Orthop* **84**, 197–199

Hulth, A. & Johnell, O (1976) Cell proliferation in the bone marrow and thymus following partial bone marrow aspiration *Experientia (Basel)* **32**, 1577

Lasalvia, E, Garcia Giralt, E & Macieira-Coelho, A (1970) Extraction of an inhibitor of DNA synthesis from human peripheral blood lymphocytes and bovine spleen *Rev Europ Etud Clin Biol* **15**, 789–792

Mankin, H J (1963) Localization of tritiated thymidine in articular cartilage of rabbits III Mature articular cartilage *J Bone Jt Surg* **45-A**, 529–540

Mankin, H
of imr
stathmoki
graphic study *Clin Orthop* **34**, 170–183

Mankin, H J (1968) The effect of aging on articular cartilage *Bull N Y Acad Med* **44** 545–552

Mejbaum, W (1939) Über die Bestimmung kleiner Pentosemengen, insbesonder in Derivaten der Adenylsaure *Z Physiol Chem* **258**, 117–120

Moorhead, J F, Paraskova Tchernozenski, E, Pirrie, A J & Hayes, C (1969) Lymphoid inhibitor of human lymphocyte DNA synthesis and mitosis in vitro *Nature (Lond)* **224**, 1207–1208

Saetren, H (1956) A principle of auto-regulation of growth Production of organ specific mitose-inhibitors in kidney and liver *Exp Cell Res* **11**, 229–232

Telhag, H (1972) Mitosis of chondrocytes in experimental "osteoarthritis" in rabbits *Clin Orthop* **86**, 224–229

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TORSIONAL STRENGTH AND GEOMETRY OF DIAPHYSEAL BONE

An Experimental Study on Dogs

P NETZ, K. ERIKSSON & L STRÖMBERG

[illegible]

A previously presented method for measuring the torsional strength of diaphyseal bones has been used to study the effect of direction of twist upon the torsional strength and stiffness of diaphyseal canine bones No significant effect of the direction of twist upon the studied properties has been found The reason for the observed twist direction independence of the torsional strength and stiffness is assumed to be the adaptation of the diaphyseal bone architecture to functional demands.

Key words bone, experimental measurement of bone stiffness experimental measurement of bone strength, maximum torque capacity strength properties

Accepted 8 iii 78

The maximum torque capacity is considered a suitable measure of strength of diaphyseal bones (in the following referred to as long bones) Torsion testing has been used by previous investigators to study the strength of long bones themselves or the effect of different treatments upon their strength (Burstein & Frankel 1971, Burstein et al 1972a, Sammarco et al 1971, Uhtoff & Duboc 1971, Mensch et al 1976, Stromberg & Dalén 1976a, b)

Previously, both bones of a pair have, with few exceptions, been twisted either inwardly or outwardly (Sammarco et al 1971, Stromberg & Dalén 1976), that is, the twist direction with respect to the bone geometry has been the same for both bones and the possible effect of the twist direction upon the torsional strength has been eliminated Others have not stated the actual twist direction at the tests, obviously assuming this to have no effect upon the torsional strength (Burstein et al 1972a, Mensch et al 1976) Moreover, in the literature no report has been found where the effect of the anatomical asymmetry of bones upon their torsional strength has been studied From the point of view of strength of materials nothing contradicts the assumption that the torsional strength of an asymmetric body depends upon the direction of twist.

The aim of this study is to elucidate the effect of the anatomical asymmetry of long bones upon their torsional strength and

Financial support was obtained from the Swedish Medical Research Council (Project no B 77-17X-04788-02), and from the Trygg-Hansa Research Fund for Bodily Injury in Personal Accident Insurance

The effect has been studied by ing bones of a related pair in different ons with respect to the bone geometry he torsional tests.

ATERIAL

. test material chosen was 7 related pairs of and 13 pairs of tibiae, with closed physeal lines, from long legged dogs of both . and of varying breed From each related pair bones, one was selected at random for outward st and the other for inward twist

he animals were sacrificed with lethal doses of sodium (Nembutal®, Abbott Laboraes, USA) administered i.v Immediately after the bones were freed of all soft tissue the periosteum. The bones were wrapped gauze saturated with physiological saline on and inserted into plastic bags. After the bags were stored in a freezer at a of −30°C. Prior to testing the bags put into physiological saline solution at C for 2 hours. Both bones of a related pair always simultaneously frozen or thawed. The were taken from the saline solution only imely prior to testing The time interval the tests of two related bones was in all s less than 10 minutes.

AL TESTING PROCEDURE

bones were twisted to fracture in a special for torsional testing of long bones. e stress concentrations in the bones were vented by using a previously described method fixation of test bones in the twist machine s (Stromberg & Dalén 1976a). During the test torque-time relationship was plotted on a time recorder (Hewlett Packard 7005 B). The ular velocity of the torsion machine is constant independent of torque in the test range The ue-twist curve for a bone is thus readily by calibrating the time axis in degrees of t. Bone material is visco-elastic, that is, its hanical properties are time-dependent Elhaney & Byars 1965, Burstein & Frankel 3 Sammarco et al. 1971, Burstein et al.). Previous studies have shown that the torque capacity and stiffness are in of the angular velocity in the range 3–12 degrees per second (Strömberg & Dalén 1976a). This means that the time-dependence is negligible in the angular velocity range studied. In view of this, the angular velocity was set at 6 degrees per second in the present study Prior to each test the equipment was calibrated against a known torque, and zero drift of the time base recorder was checked.

The experimental error of the method is less than ~3 per cent This includes the error due to the scatter of the maximum torque capacity of related pairs of diaphyseal bones twisted in the same direction with respect to the bone geometry Thus the precision of the method is such that any difference larger than ~3 per cent between the torsional strength of a test bone and its control is detected inevitably

RESULTS AND CALCULATIONS

From the torque-twist curve the maximum torque capacity was obtained (Figure 1) The maximum torque capacity is represented by the coordinates of the point on the torque-twist curve corresponding to the onset of ultimate failure of a bone The first part of the torque-twist curve – from zero up to a critical torque – is linear The corresponding bone stiffness is expressed as torque per unit twist.

Measurements of twist angle and energy were not studied in this investigation

The difference in the recorded parameters of related bones was expressed in per cent of the mean value for the pair The mean value of the difference and the standard deviation for the whole sample of bones were also calculated The measured values of the inwardly and outwardly twisted samples of long bones were analysed according to the paired t-test and the significance determined

The results are shown in Tables 1 and 2. No significant effect ($P > 0.05$) was found of the direction of twist upon the maximum torque capacity or the stiffness of related bones twisted in opposite directions with respect to the bone geometry In all bones tested a sudden spiral fracture occurred at the diaphysis.

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Accepted 8 iii 78

The maximum torque capacity is considered a suitable measure of strength of diaphyseal bones (in the following referred to as long bones) Torsion testing has been used by previous investigators to study the strength of long bones themselves or the effect of different treatments upon their strength (Burstein & Frankel 1971, Burstein et al 1972a, Sammarco et al 1971, Uhtoff & Duboc 1971, Mensch et al 1976, Stromberg & Dalén 1976a, b)

Previously, both bones of a pair have, with few exceptions, been twisted either inwardly or outwardly (Sammarco et al 1971, Stromberg & Dalén 1976), that is, the twist direction with respect to the bone geometry has been the same for both bones and the possible effect of the twist direction upon the torsional strength has been eliminated Others have not stated the actual twist direction at the tests, obviously assuming this to have no effect upon the torsional strength (Burstein et al 1972a, Mensch et al 1976) Moreover, in the literature no report has been found where the effect of the anatomical asymmetry of bones upon their torsional strength has been studied From the point of view of strength of materials nothing contradicts the assumption that the torsional strength of an asymmetric body depends upon the direction of twist

The aim of this study is to elucidate the effect of the anatomical asymmetry of long bones upon their torsional strength and

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Table 2 Stiffness of paired long bones (femora and tibiae from 20 dogs)

	Dog no	Stiffness Nm/degree Inward rotation	Outward rotation	Percentage difference
femora	1	1 42	1 54	−8 1
	2	1 40	1 33	5 1
	3	1 30	1 40	−7 4
	4	1 33	1 38	−3 7
	5	1 75	1 67	4 7
	6	1 67	1 69	−1 2
	7	1 53	1 53	0 0
tibiae	8	0 71	0 69	2.9
	9	1 00	1 08	−7 7
	10	0 77	0 75	2.6
	11	0 79	0 85	−7 3
	12	1 00	0 96	4 1
	13	0 89	1 00	−11 6
	14	0 75	0 75	0 0
	15	0 58	0 56	3 5
	16	0 94	0 89	5 5
	17	1 19	1 25	−4 9
	18	0 69	0 70	−1 4
	19	1 56	1 56	0 0
	20	1 11	1 11	0 0

e of the paired bones was rotated inwardly and the contralateral one was rotated outwardly The erence between the inwardly rotated and the outwardly rotated bone is expressed in per cent of the an value of the two bones. Angular velocity was 6 degrees/second The rotational direction had no nificant influence on the stiffness. (Mean = −1 25 per cent, S D −5 1 per cent Paired t test 0 05)

ction is the same for both bones with to the bone geometry, but if one bone wisted inwardly and the other outwardly, n the twist direction is different with to the bone geometry

e evident difference in geometry ween the two bones of a related pair might aken to suggest that the torsional strength ends upon the direction of twist The ional strength depends, however, not only n the geometry of the long bone segments, also upon the internal architecture and ribution of the quantity of bone material arying quality and the presence and dis- ution of inhomogeneities in different parts the diaphyseal bone segments. The asymmetry of diaphyseal bones is most pronounced in the bone segments where the main muscle attachments are situated and in segments close to the bone ends. The asymmetry, however, decreases steadily as the bone segment where the area of muscle attachment attains a minimum is approached In this segment the bones are almost cylindrical and the difference in geometry is consequently smallest As minor variations in geometry of an idealized homogeneous body, according to the theory of strength of materials (Burstein & Frankel 1971), have little effect on the torsional strength, the effect of the remaining difference in geometry is of minor importance

The cylinder construction is a reasonable compromise to minimize the weight of a body to sustain axial, bend and torque loads acting individually or in combination

As regards torque, the geometrical asymmetry is obviously compensated for by a corresponding asymmetry of the internal bone architecture so as to render the torsional strength independent of rotation direction This is evidently a logical consequence of the principle of adaptation to functional demands

Stiffness is a well defined and easily quantified mechanical property of a body It defines the twist response of the bone to a given torque The stiffness of an anatomically asymmetric canine bone is independent of the direction of twist, or, the twist deformation of the bone is of the same magnitude for inward or outward twist with a given torque This is also an evident consequence of the *principle of adaptation to functional demands*

Furthermore, the present results show that the maximum torque capacity and the stiffness of canine long bones are both symmetrical properties, or, independent of the direction of twist This indicates the ability of a long bone to adapt itself to the load bearing functional demands, in spite of a less favourable outer geometry, caused by the necessary soft tissue attachments. The use of one long bone of a related pair as a torsional test specimen, and the other as a control, with no regard to the direction of twist, is therefore justified

REFERENCES

Burstein, A H & Frankel, V H (1968) The viscoelastic properties of some biological materials *Ann N Y Acad Sci* 146, 158–175

Burstein, A H & Frankel V H (1971) Technical note A standard test for laboratory animal bone *J Biomech* 4, 155–158

Burstein, A H, Currey, J, Frankel, V H Heiple K. G, Lunseth, P & Vessely, J C (1972a) Bone strength The effect of screw holes. *J Bone Jt Surg* 54-A, 1143–1156

Burstein, A H, Currey, J D, Frankel V H & Reilly, D T (1972b) The ultimate properties of bone tissue the effect of yielding *J Biomech* 5, 35–44

McElhaney, J H & Byars, F (1965) Dynamic *response of biological materials.* ASME paper 65-WA/HUF 9

Mensch, J S, Markolf K L, Roberts, S B & Finerman, G M (1976) Experimental stabilization of segmental defects in the human femur *J Bone Jt Surg* 58-A, 185–190

Sammarco, G J, Burstein, A H, Davis, W L & Frankel, V H (1971) The biomechanics of torsional fractures The effect of loading on ultimate properties *J Biomech* 4, 113–117

Stromberg, L & Dalén, N (1976a) Influence of a rigid plate for internal fixation on the maximum torque capacity of long bones *Acta chir scand* 142, 115–122

Stromberg, L & Dalén, N (1976b) Experimental measurement of maximum torque capacity of long bones. *Acta orthop scand* 47, 257–263

Stromberg, L & Dalén N (1976c) The influence of freezing on the maximum torque capacity of long bones. *Acta orthop scand* 47, 254–256

Uhtoff, H K & Duboc, F L (1971) Bone structure changes in the dog under rigid fixation *Clin Orthop* 81, 165–170

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VALUATION OF FRACTURE HEALING IN MAN BY RIAT ^{99m}Tc-Sn-PYROPHOSPHATE SCINTIMETRY

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Serial ^{99m}Tc-pyrophosphate (^{99m}TcPP) uptake measurements were performed, during the healing period, in 12 patients with fracture of the distal end of the radius without displacement A peak value in uptake ratio was seen within 4 weeks in all patients For clinical reasons the patients were divided into a normal healing and a slow healing group ^{99m}TcPP uptake at 6 weeks after the fracture was significantly higher in the slow healing group Quantitation of the healing process in forearm fractures is possible using ^{99m}TcPP and a gamma camera and concentrating on small selected areas of interest

Key words forearm fracture, scintimetry ^{99m}Tc-pyrophosphate healing course

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e use of ^{99m}Tc-Sn-pyrophosphate mTcPP) as a radio-pharmaceutical in nical work is well established in the early of skeletal metastases and primary ne tumours Furthermore, a great deal of erest has been devoted to the application other radioactive tracers to study osteo- s of the head of the femur in fractures, of the tibial shaft displaying delayed and non-union, infected endosprotheses some metabolic bone diseases (Merrick

Bone-seeking tracers have been less in- isively studied during normal healing pro- sses, although this application has been ggested by several authors (Bauer & 1959, Wendeberg 1961, Bessler 58, Bauer 1975, Puranen et al. 1975, thall et al 1976)

The present study was undertaken to in- the change in ^{99m}TcPP uptake in a fracture of the distal end of the radius during the healing period, and to correlate the clinical healing to ^{99m}TcPP scintimetry

MATERIAL AND METHODS

Twelve patients, all women aged from 40 to 76 years (mean 56 years) were examined All had fractures, without displacement of the distal end of the radius The patients were selected in such a way that the radiological appearance of the fractures was identical.

Scintigraphy was performed every second week over a period of 6 to 8 weeks after the trauma A final scintigraphy was made 24 weeks after the accident in eight of the patients. In four patients the final scintigraphy was omitted in one case because of refracture, in one because of operation on the wrist and the remaining two patients refused further follow-up

In 10 patients admitted for bone scintigraphy because of diseases in the spine or lower extremities but without any injury or disease in the



Figure 1 Scintigraphic appearance of forearms and hands (A) digitalized picture in 64×64 points frame (B) 2×2 points area of interest at the fracture site and a symmetrical area on the contralateral arm

upper extremities, a single scintigraphy of the forearms was obtained as a control

A total of 61 scintigraphic examinations were performed

Six to 10 mCi ^{99m}TcPP (Solcoscint ®Diphosphate, Solco Nuclear Basle, Switzerland) was given intravenously Three hours later scintigrams were obtained with a General Electric Maxicamera using a high resolution parallel hole low energy collimator The systemic resolution was 10 mm 250 000 counts were collected and the data stored on magnetic tape in a 64×64 points frame for later digital analysis (General Electric Med Stor®)

In order to obtain reproducible and symmetrical geometry a PVC mould with excavations for the forearms was used The dorsal plaster casts were left *in situ* and the forearms were examined from the volar surface

In the digitalized picture of the forearms an area of interest was selected in the fracture region being the area showing the maximum of collected counts A symmetrical area of the same size was located in the image of the contralateral forearm (Figure 1) The size of the areas chosen (2×2 points in the frame) was the minimal area which was possible using the available equipment The area corresponded to approximately 1 6×1 6 cm on the examined object. In the non injured control patients equivalent areas in the distal end of the radius were examined.

The uptake of ^{99m}TcPP in the fracture was expressed as the ratio between the counts recorded in the two areas described 3 500–15 000 counts were recorded at the fracture site and 500–2 000 in the contralateral arm Thus the coefficient of variation of the ratios between the fracture site and the control arm was less than 4 5 per cent.

Healing of the fracture was evaluated by recording disappearance of local pain and achievement of free mobility The clinical examination was carried out by a member of the staff of the orthopaedic department who had no knowledge of the scintimetric results Additionally the immobilization time in plaster was recorded

Blood samples were collected to estimate the calcium and vitamin D status 25 hydroxy cholecalciferol was measured by a competitive protein binding assay according to Haddad & Chyu (1971)

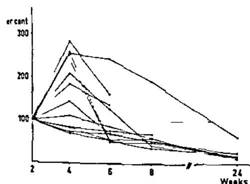
Statistical evaluation was made using Wilcoxon rank sum tests for paired and unpaired data

RESULTS

As illustrated in Figure 2 a variation in the ^{99m}TcPP uptake rate was seen after the fracture

The accumulation of ^{99m}TcPP increased to reach a maximum within 4 weeks after the injury This was followed by a decrease to the lowest values 24 weeks after the fracture

A fracture of the distal end of the radius without displacement is normally united and free of local pain within 5 weeks. Based upon



igure 2 The percentage variation of ^{99m}TcPP ptake ratio related to the 2-week value

his criterion the patients were separated into wo groups (Table 1) Seven patients healed vithin 5 weeks and five patients had a ealing time of more than 5 weeks urthermore, the latter group required a ignificantly longer period for full mobility of he wrist and fingers to be achieved $P<0.05$) The plaster casts were applied for shorter period in the fast healing group, but he difference was not significant

The results of scintimetry showed no lifference between the two groups after 2 and 4 weeks, whereas the ^{99m}TcPP uptake 6 weeks after the fracture was significantly higher in the slow-healing group ($P<0.05$) No difference was seen after 8 and 24 weeks (Table 2)

After 6 weeks all patients with normal healing had values below those found in the second week This was, however, also found in one patient in the slow-healing group

Normal values of serum calcium (2.12 ± 0.26) and (2.15 ± 0.20) and slightly elevated 25-hydroxycholecalciferol values (50.5 ± 14.8) and (40.3 ± 15.4) were seen in the normal and the slow-healing groups, respectively

The patients without fractures had uptake ratios of 0.93 ± 0.05 (mean ± s.d)

DISCUSSION

The present investigation was undertaken to study the scintigraphic course of healing of fractures of the distal end of the radius This type of fracture was chosen because the healing usually proceeds without delayed or

Table 1 Clinical evaluation of healing in normal (A) and slow healing (B) patients

Group	Disappearance of local pain (range in weeks)	Fixation with plaster casts (range in weeks)	Free mobility (range in weeks)
A	4–5	4–5	6–7
B	6–10	5–7	8–11
		NS	$P<0.05$

Table 2 Variation of uptake ratio in the normal (A) and slow healing group (B) (Mean ± s d)

Weeks	2	4	6	8	24
Group A $n=7$	10.3 ± 3.9	12.2 ± 3.2	6.7 ± 3.7	4.8 ± 3.0	1.8 ± 0.7
Group B $n=5$	8.6 ± 3.0	15.7 ± 3.9	11.5 ± 2.4	7.6 ± 3.1	2.5 ± 1.3
	NS	NS	$P<0.05$	NS	NS

non union The availability of reproducible values from the contralateral arm also makes these fractures particularly suitable for this kind of study Moreover, it might serve as a model for the healing process of other types of fractures where exact clinical and radiological evaluation is more difficult

In the first radionuclide uptake study in fractures in man, Bauer & Wendeberg (1959) demonstrated with cation tracers ^{85}Sr and ^{45}Ca a maximal activity 6 weeks after a hip fracture These patients were investigated under rather varying conditions

Scintimetric evaluation of fracture healing has been carried out on tibial shaft fractures (Wendeberg 1961, Muheim 1973, Puranen et al 1975) Generally the maximum uptake at the fracture site was seen 4–8 months after the injury In delayed healing Bauer & Wendeberg (1959) found a high uptake ratio, whereas Puranen et al (1975) observed low uptake ratios in delayed union This discrepancy was noted by Muheim (1973) and may be related to different types of delayed union

In the present study a different tracer was used ^{99m}TcPP is preferentially bound by immature collagen, whereas the cation tracer ^{45}Ca is bound predominantly in the bone mineral (Kaye et al 1975) This may explain the earlier peak activity seen in our studies Furthermore, it is well known that there are differences in the natural healing course of fractures of the forearm and tibial fractures

The combination of good information density and safety of the radionuclide deposit at the lesion site, facilitated by the vascularity of the fracture make ^{99m}TcPP a good tracer for describing the events of fracture in the healing period (Lentle et al 1976)

As mentioned earlier maximal activity in small selected areas of interest was measured because they were exactly defined and reproducible when working with a digitalized computer system connected to a gamma camera This is in accordance with the results reported by Gumerman et al (1977) who were able to indicate the course of healing by sequential scanning with quantitative analysis of the fracture line in a rabbit model using ^{99m}Tc methylenediphosphonate

A relation between osteoporosis, osteomalacia, and occurrence of juxta articular fractures has been described (Aaron et al 1974) Seventy per cent of women with such fractures are osteoporotic (Bollet et al 1965). Furthermore, it has been demonstrated that 30 per cent of osteoporotic patients have histological but not biochemical signs of osteomalacia (Lund et al 1977 Sørensen et al 1977) Thus we examined Se-calcium and 25 OH-cholecalciferol to evaluate the vitamin D metabolism This metabolite affords the best evaluation of vitamin D-status according to Avioli & Haddad (1977) The metabolic analyses were done to exclude differences in vitamin D metabolism in the groups described Several authors (Harris et al 1965 Rosenthall & Kaye 1975, Fogelman et al 1977) have described alteration in radionuclide uptake in patients showing hypo- as well as hypervitaminosis D

Our preliminary investigation indicates that it is possible to quantitate the healing process using ^{99m}TcPP and a gamma camera and concentrating on small areas of interest By this method fractures of the distal end of the radius can be separated into normal and slow healing types This technique can probably be applied to other fractures

REFERENCES

Aaron J E Gallagher J C & Nordin B E C (1974) Seasonal variation of histological osteomalacia in femoral neck fractures. *Lancet* ii 84–85

[illegible]

skeletal lesions in man [illegible] 558–580

Bauer, G (1975) Progress in the use of radionuclides in orthopaedics. *Acta orthop scand* 46, 315–322

Bessler, W T (1968) Skeletal scintigraphy as an aid in practical roentgenographic diagnosis. *Amer J Roentgenol* 102, 899–907

Bollet, A J, Engh, G & Parson, W (1965) Epidemiology of osteoporosis. *Arch int Med* 116, 191–194

Fogelman, I, McKillop, J H, Cowden, E A, Fine, A, Boyce, B, Boyle, I T. & Greig, W R (1977) Bone scan findings in hypervitaminosis D Case report *J nucl Med* 18, 1205–1207

Gumerman, L, Fogel, S, Goodman, M, Hanley, E, Kappakas, G, Levine, G & Kikuike, A (1977) Fracture healing Evaluation utilizing radionuclide bone imaging Paper presented at 24th annual meeting of Amer Soc Nucl Med *J nucl. Med* 18, 622

Haddad, J G & Chyu, K J (1971) Competitive protein binding radioassay for 25-hydroxycholecalciferol. *J clin. Endocr* 33, 992–995

Harris, F, Hoffenberg, R. & Black, E G (1965) The radioisotope osteogram in Rickets. *Clin Sci.* 28, 75–82

Kaye, M, Silverton, S & Rosenthall, L (1975) Technetium-99m-Pyrophosphate Studies in vivo and in vitro *J nucl. Med* 16, 40–45

Lentle, B C, Russell, A. S, Percy, J S, Scott, J R. & Jackson, F I (1976) Bone scintiscanning updated *Ann int Med* 84, 297–303

Lund, B., Andersen, R B, Christensen, M, Friis, T, Hjort, L, Jørgensen, F S, Melsen, F, Mosekilde, L & Sørensen, O H (1977) The effect of 1-alfa hydroxycholecalciferol on calcium balance and bone histology in a randomized trial *Vitamin D, biochemical, chemical and clinical aspects related to calcium metabolism.* Ed Norman A W et al, pp 399–406 W de Gruyter, Berlin, New York

Merrick, M V (1975) Review article – Bone scanning *Brit J Radiol* 48, 327–351

Muheim, G (1973) Assessment of fracture healing in man by serial ^{87m}Strontium-scintimetry *Acta orthop scand* 44, 621–627

Puranen, J, Kiviniitty, K. & Kaski, P (1975) Strontium-85 profile counting in fractures of the tibial shaft *Acta orthop scand* 46, 569–578

Rosenthall, L, Hill, R O & Chuang, S (1976) Observation on the use of ^{99m}Tc-phosphate imaging in peripheral bone trauma *Radiology* 119, 637–641

Rosenthall, L. & Kaye, M (1975) Technetium-99m-pyrophosphate kinetics and imaging in metabolic bone disease. *J nucl Med* 16, 33–39

Sørensen, O H, Reimann, J, Kjaer, J, Andersen, R B, Lund, B, Friis, T & Hjorth, L (1977) Effect of 1-alfa-hydroxycholecalciferol in senile osteoporosis and in bone loss following prednisone treatment. *Israel J med Sci* 13, 253–258

Wendeberg, B (1961) Mineral metabolism of fractures of the tibia in man studied with external counting of Sr^{85} *Acta orthop scand*, Suppl. 52

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STRUCTURAL ROLE OF BONE APATITE IN HUMAN FEMORAL COMPACTA

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Tensile and compressive strength of human femoral compacta have been shown to be related ($P \ngtr 0\,005$) to the average bone apatite crystallite length (D_{002}) as determined by X-ray diffraction line breadth measurement. However, statistical variance of crystallite length was not sufficient to explain observed differences in mechanical properties these differences being primarily due to variation in mineral density Average bone apatite [illegible]

but that this is not a major factor in determining fracture incidence in the elderly

Key words bone apatite, crystallite length mechanical properties

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Compact bone is a composite material comprising collagen fibrils set in a non-collagenous matrix and incorporating calcium hydroxyapatite-like mineral inclusions (Wainwright et al. 1976) In addition, Posner (1969) has reported the presence of mineral in the form of amorphous calcium phosphate in bone Correlation of the mechanical properties of bone tissue with mineral content is well established (Vose & Kubala 1959, Vose et al 1961, Mather 1968, Currey 1969, Currey & Butler 1975), and increased incidence of bone fracture in the elderly (Knowelden et al 1964) has been related to a decline in bone mineral content with age (Mulligan et al 1975) Despite evidence of age-related change in bone apatite crystallite length and orientation (Chatterji & Jeffery 1968, Chatterji et al. 1972), the structural role of apatite in compact bone has not been directly investigated

We have used X-ray diffraction line breadth measurement (Holmstrand 1957) to assess average bone apatite crystallite length (D_{002}) in human bone samples of differing biological age Tensile and compressive mechanical properties were measured in the same bones and considered in relation to crystallite length

MATERIALS AND METHODS

Human compacta excised post-mortem from 14 males and 15 females, ranging from 3½ to 87 years of age, was studied. All samples were removed from the proximal half of the femoral shaft, placed in polythene bags to prevent drying, and stored at −20°C until required Separate portions were designated for the preparation of tensile and compressive test-pieces and X ray diffraction powder samples. A steel template was used to prepare tensile test pieces 3 1 mm thick and with a "waisted" portion 35 mm in length and 3 8 mm in width. Cylindrical compressive test-pieces 5 1 mm in diameter and 7 5 mm in length were produced with a diamond tipped core drill Where the bone was of sufficient size, mechanical test-pieces were produced from four cross-sectional quadrants, this proved possible with 27 bones in the case of compressive test-pieces, and with 24 bones in the tensile test-pieces. Mechanical test-pieces remained moist when tested to destruction at a strain rate of 10^{-3} s^{-1}, as described in an earlier publication (Smith & Smith 1976a) The values of each tensile or compressive property determined for the four quadrants in each bone were averaged to reduce variation due to regional differences.

X-ray diffraction bone powder samples were produced by crude milling and subsequent wet-grinding with isopropyl alcohol in a micronizing mill. Grinding for 2 minutes produced a powder with particle size in the range 50–150 micron. The minimum particle dimension was large enough to ensure that the surface layer, which might contain crystallites ground to a size sufficiently small to produce X ray diffraction line broadening, comprised less than one per cent of particle volume (Smith 1975). The line profile of the bone apatite (002) reflection obtained using nickel-filtered copper K_α radiation was monitored with a Philips vertical goniometer Type PW 1140 The goniometer was fitted with 1° divergence and scatter slits and a 1 mm receiving slit, and the scintillation detector was rotated at ¼° 2θ per minute. Instrumental line broadening produced by this experimental arrangement was measured by recording the (111) reflection for each of ten NaCl standard powder samples possessing crystallite size too large (50–150 micron) to contribute to line broadening

Calculations

Bone apatite (002) X-ray diffraction line profiles were shown to be described accurately ($r \geq 0\,99$) by the Cauchy equation $y = 1/(1 + K^2X^2)$ Observed line breadth at half peak intensity was corrected for broadening due to wavelength spread accurate estimate of instrumental line broadening at a diffraction angle close to that of the bone apatite (002) reflection. Hence, bone apatite (002) pure line breadth (β_{002}) was calculated by the method of Alexander & Klug (1950)

Pure line breadth results from small crystallite size and lattice strain (Warren & Averbach 1950) Harper & Posner (1966) have claimed that bone contains amorphous calcium phosphate (ACP), which causes diffuse X-ray scattering and gives rise to additional line broadening However, ACP converts rapidly to hydroxyapatite in the presence of the precipitating solution (Termine et al 1970), and there is no satisfactory theory to explain why this should not occur *in vivo* The authors (Smith & Smith 1976b) do not believe that bone contains a substantial quantity of ACP, and Posner et al (1975) now even express some uncertainty as to the short-term presence of ACP in bone as a chemical precursor in the formation of bone apatite *in vivo*

Moreover, calculation based on accepted values for the rate of bone turnover in the adult (Villaneuva et al 1966) shows that if ACP is precipitated in bone and converts to hydroxyapatite within 24 hours, then the proportion of amorphous bone mineral will be less than 0 03 per cent of the total, and would not significantly affect X-ray diffraction line breadth.

It is known that the Cauchy form of pure line profile, as observed in our investigation, is characteristic of pure line broadening due to small crystallite size (Posner et al 1965, Schoening 1965). Thus, an estimate of bone apatite average crystallite size (D_{002}) normal to the (002) planes, can be calculated from the Scherrer equation

$$D_{hkl} = C\,\lambda/\beta_{hkl}\cos\theta_{hkl}$$

where λ is the intensity-weighted mean wavelength of X-radiation, θ_{hkl} is the Bragg angle for the (hkl) planes, β_{hkl} is the pure line breadth measured in radians, and C is a constant dependent upon the definition of β and the crystallites shape distribution Absolute determination of D_{hkl} is inaccurate due to uncertainty as to the value of C, although Bragg (1919) has shown that if β is defined as the pure line breadth at half maximum intensity, then C takes a value of approximately 0 9 and is relatively insensitive to differences in shape This value of C was assumed in the present investigation Since the bone apatite c-axis has been shown to be parallel to the long axis of the crystallite (Engstrom & Finean 1953), D_{002} is equal to the average crystallite length.

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STRUCTURAL ROLE OF BONE APATITE IN HUMAN FEMORAL COMPACTA

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Tensile and compressive strength of human femoral compacta have been shown to be related ($P \ngtr 0.005$) to the average bone apatite crystallite length (D_{002}) as determined by X-ray diffraction line breadth measurement. However, statistical variance of crystallite length was not sufficient to explain observed differences in mechanical properties, these differences being primarily due to variation in mineral density Average bone apatite crystallite length was not found to change significantly with biological age ($P = 0.30$) over the range 3½ to 87 years. It is concluded that increased bone apatite crystallite length is detrimental to the structural role of the skeleton but that this is not a major factor in determining fracture incidence in the elderly

Key words bone apatite, crystallite length mechanical properties

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Compact bone is a composite material comprising collagen fibrils set in a non-collagenous matrix and incorporating calcium hydroxyapatite-like mineral inclusions (Wainwright et al 1976) In addition, Posner (1969) has reported the presence of mineral in the form of amorphous calcium phosphate in bone Correlation of the mechanical properties of bone tissue with mineral content is well established (Vose & Kubala 1959, Vose et al 1961, Mather 1968, Currey 1969, Currey & Butler 1975), and increased incidence of bone fracture in the elderly (Knowelden et al 1964) has been related to a decline in bone mineral content with age (Mulligan et al 1975) Despite evidence of age-related change in bone apatite crystallite length and orientation (Chatterji & Jeffery 1968, Chatterji et al. 1972), the structural role of apatite in compact bone has not been directly investigated

We have used X-ray diffraction line breadth measurement (Holmstrand 1957) to assess average bone apatite crystallite length (D_{002}) in human bone samples of differing biological age Tensile and compressive mechanical properties were measured in the same bones and considered in relation to crystallite length

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ᴉ.ᵹı ROPHIC CALCIFICATION IN TUBERCULAR ᴴ JNS OF BURSAE

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Four patients with extensive dystrophic calcification in osteoarticular tubercular lesions of relatively short duration, are described All lesions healed satisfactorily after treatment with antitubercular drugs combined in some cases with *en bloc* excision

Key words dystrophic calcification, lymph nodes, tubercular lesions osteoarticular tuberculosis

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ystrophic calcification in long-standing lesions of lymph nodes and is a known entity However, tensive dystrophic calcification in osteo-tubercular lesions of shorter duration not been reported Hence, the clinical diological operative and histopathological ures of four such patients with extensive strophic calcification around the hip and bow are described

ASE REPORTS

I

R.V., a 30-year-old mean, presented in vember 1973 with a 6-year history of pain and elling over the left trochanteric region and the ce of similar swelling and pain over the it trochanteric region in the course of the 3 years. The swellings were associated h *fever* Following treatment with antibiotics antitubercular drugs the swellings had temporarily but gradually the symptoms recurred.

Clinical examination of the patient at the initial ion revealed a diffuse swelling on either of the trochanteric and gluteal region There was a sinus on the left side, discharging thin serous fluid The skin around the sinus was pigmented and adherent to the underlying

[illegible]

were enlarged and tender There were no clinical signs of hip joint disease

Radiological examination showed extensive calcifications of the trochanteric region of both hips without any involvement of the joints or the pelvic bones (Figure 1)

Exploration of the right swelling produced necrotic and calcareous matter Histological examination of the specimen showed a characteristic tubercular lesion with dystrophic calcification (Figure 2)

Following treatment with antitubercular drugs the lesions healed

Case 2

M.A., a 12-year-old boy was admitted on 12.10 76 with complaints of a tender swelling in the left gluteal region The symptoms had begun after a fall from a bicycle 11 months previously The swelling had increased in size with episodes of fever and decreased after treatment, in 7–10 days. At admission of diffuse swelling (Figure 3) was seen and *on deep* palpation a hard mass with restricted mobility was *felt* under the gluteus maximus Local temperature was raised. The boy



Figure 1 X ray of the pelvis including both hips shows an extensive calcified mass in the trochanteric region on both sides (Case 1)



Figure 2 Microphotograph of Case 1 showing tubercular granulomas with large areas of calcification Note also one large giant cell with bipolar arrangement of the nuclei (H&E ×160)



Figure 3 Clinical photograph showing diffuse swelling in the left trochanteric region (Case 2)

had lumbar lordosis and with the exception of a flexion deformity of 40 degrees, the hip joint was clinically free from disease Wasting of the glutei and the quadriceps muscles was also present. X ray of the region showed a soft tissue swelling and extensive calcification similar to Case 1

The swelling which was situated beneath the gluteus maximus, was excised and was found to consist of tubercular pus with cheesy material and calcified masses.

Microscopic examination showed a tubercular lesion with extensive dystrophic calcification. The patient recovered satisfactorily following treatment with antitubercular drugs.

Case 3

D N., a 17 year-old boy attended the hospital in July 1974 with complaints of a swelling of the anteromedial aspect of the left elbow of insidious onset 1 year previously (Figure 4) The elbow was ankylosed in extension because of an accident 3 years earlier



Figure 4 Clinical photograph showing swelling over the front of the elbow (Case 3)

Clinical examination revealed a localized, tense, fluctuant nonpulsatile swelling over the anteromedial aspect of the left elbow Movement of the elbow was restricted to 0–30 degrees.

Radiological examination of the elbow showed a well-delineated, pedunculated soft tissue swelling arising from the anterior aspect of the elbow joint with evidence of extensive calcification within the swelling There were destructive changes in the elbow joint (Figure 5). *En bloc* excision of the swelling was performed It contained tubercular pus and calcified debris.

The patient made a good recovery after treatment with antitubercular drugs and even regained a good range of elbow motion.



Figure 5 X-ray of the left elbow showing well delineated, pedunculated cystic swelling over the anteromedial aspect of the elbow joint (Case 3)



Figure 6 X-ray of the right elbow showing soft tissue swelling with a calcified mass behind the distal end of the humerus and the elbow joint (Case 4)

Case 4

M.D, a 7-year-old girl, presented with complaints of pain and swelling on the posterior aspect of the right elbow which had begun 2 months previously Clinical examination revealed a well defined oblong non tender swelling along the posterior aspect of the lower fourth of the arm The swelling was mobile with a variable consistency from soft and fluctuant to hard and nodular The local temperature of the swelling was raised. Elbow motion ranged from 30–120 degrees. Axillary lymph nodes were enlarged and tender

The patient also had a discharging sinus from her right tibia

X-rays of the [illegible]
ca [illegible]
th- [illegible]
the right tibia showed periosteal reaction and sclerosis in the upper third of the tibia

En bloc excision of the swelling was performed The mass contained typical tubercular pus with cheesy material and a calcified nodular mass. The patient regained full function of the elbow following antitubercular drugs

ISCUSSION

[illegible] tion of calcium salts in dead and [illegible] tissues is termed dystrophic calcification and is found in various pathological con[illegible] of which tuberculosis is one of the common (Anderson 1971, Florey 1970) [illegible]berculous calcifications are found most frequently in lymph nodes and in cold abscesses of long standing In the four cases presented here, extensive dystrophic calcification was seen in three cases of relatively short duration, i.e, 2 months to 1 year, the first case had a disease process lasting 6 years. All the four cases posed clinical and radiological diagnostic problems and the tuberculous nature of the lesions was revealed only after exploration and histopathological examination Even though tuberculosis in general and osteoarticular tuberculosis in particular is very common in our country, such extensive dystrophic calcification is very unusual and to our knowledge has not been described earlier in the literature

ACKNOWLEDGEMENT

Sincere appreciation is expressed to Mr D K. Mathur for photographic assistance and to Sri Prem Nath for secretarial assistance.

REFERENCES

Anderson, W A D (1971) Dystrophic calcification. *Pathology*, Vol. 1, p 86, C. V Mosby & Co., Saint Louis.

Florey, L. (1970) Dystrophic calcification. *General pathology*, 4th ed., p. 435 Lloyd-Luke (Medical Books) Ltd, London.

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ATROPHY OF CORTICAL BONE CAUSED BY RIGID INTERNAL FIXATION PLATES

An Experimental Study in the Dog

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The cortical atrophy induced by a rigid internal fixation plate on diaphyseal bone was studied on the femora of seven dogs When the plate which had been in position for 7 months without previous osteotomy, was removed a pronounced reduction of the cortical bone was observed in the previously plated section of the diaphyseal bone The atrophy took the form of loss of cortical bone mainly caused by endosteal resorption with enlargement of the medullary cavity Neither periosteal resorption nor formation of woven bone under the site of the plate were observed The process of adaption to the changed stress and strain conditions, caused by the mechanical joint, i e, implants and bone was studied by means of a histological technique, and was still in progress after a period of seven months

Key words internal plate fixation adaption of cortical bone to functional demands, measurement of cortical bone atrophy

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Metal plates for internal fixation have been used to an ever increasing extent for almost a century Clinical experience from fracture treatment with internal fixation plates shows, however, that a considerable number of refractures occur (Richon et al 1967, Wade 1970) In a previous paper (Stromberg & Dalén 1976), we demonstrated that the dog femur stabilized with a rigid internal fixation plate (AOI-type) for 7 months displays, on removal of the plate, and compared with the contralateral control bone a significantly different distribution of b[illegible] and a marked reduction in m[illegible] [illegible]gle of torsion

The present [illegible] to elucidate the mo[illegible] develop con[illegible] to the bones ca[illegible]

METHODS

Anaesthesia

The surgical procedures for bone plating according to the AO group were performed under general anaesthesia which was induced with thiomebumalnatrium (Pentothal Sodium®, Abbott Laboratories Chicago, Ill USA) By means of an endotracheal tube, the dogs were connected to an Engstrom ventilator supplied with a gas mixture of oxygen and nitrous oxide Small doses of thiomebumalnatrium were administered intermittently [illegible] the operations.

Surgical [illegible]

Seven [illegible] healthy male dogs (Swedis[illegible] [illegible] were used An AO plate [illegible] four holes designed f[illegible] internal [illegible] on dogs (Synthe[illegible] Walden [illegible] as applied und[illegible] sterile [illegible] An incision w[illegible]

made through the skin and underlying fascia Both femora were exposed up to the linea aspera by an approach behind and under the vastus lateralis muscle of the quadriceps along the intramuscular septum (the 'mailbox" approach) The underlying periosteum was not detached from the bone and no osteotomy was performed The perforating vessels in the distal part of the intramuscular septum were used as reference points, so that the plates could be similarly fitted on both femora The plates were applied to both femora immediately in front of the linea aspera and fastened according to the AO method, after the plate had been modelled to the bone (Muller et al 1970) One of the plates (chosen at random) was removed and the screws refastened into the bone The soft parts were sutured in stages, using catgut in the fascia and non-absorbable sutures in the skin

Pre and postoperative care

During the operations, 500 ml of Ringer solution was administered intravenously A daily prophylactic dose of 0 5 g of ampicillin (Pentrexyl®, Bristol-Myers, *New York, N Y, USA*) was given during the first postoperative week. The dogs spent an uneventful postoperative period of 7 months in kennels They were checked daily and received adequate food and exercise

Seven months after the operations, the animals were given tetracycline (Terramycin®, Pfizer Inc., New York, N Y, USA), 0 5 g per kg body weight per os.

Sacrifice

One week after administration of tetracycline, the dogs were sacrificed with intravenous lethal doses of mebumalnatrium (Nembutal®, Abbott Laboratories).

Bone preparation

All femora were dissected from the surrounding soft tissue, but not from the periosteum The femora the test bones and the control bones, were cut in 4 0 *mm* thick cross-sectional slices. They were frozen to −40°C All the slices were submitted to X-ray examination After the radiological examination, every second slice was chosen for ashing and the rest for histological studies.

Radiological study

The radiological examinations were performed with the X ray beams parallel to the long axis of the femora. The porosity of the cortical bone and the amount of newly formed periosteal bone were estimated by means of the radiograms from the cross section of the bones The cross-sectional areas of the cortical bone and those of the medullary cavities were measured with a planimetric technique The areas were compared and the differences between those from the test bones and the corresponding ones from the control bones were noted In the measurement of cross-sectional areas, the periosteal formed bone ridges were excluded

Histological study

The slices chosen for histological studies by means of a fluorescence technique were freeze-dried to constant weight and then immediately embedded in methylmethacrylate (Olerud & Lorenzi 1970) Thin pieces were cut from the embedded slices and then reduced to a thickness of about 60 μ This process had no effect on the fluorochromes present The colours were fixed by a freeze-drying process, as they would have been partly dissolved by other dehydration procedures. The prepared histological slides were studied by fluorescence microscopy The differences between corresponding parts of the test bones and their controls were estimated

Measurement of ash weights

The amount of non-organic material in the test bones and their controls was estimated by means of an ashing procedure The slices chosen were ashed to constant weight at 600°C The differences in ash weight between the ashes from corresponding slices from the same animal were registered

RESULTS

Dispersed areas of periosteal formed bone were observed on the radiograms. The areas where the plates had been located were defined by ridges formed of periosteal bone, most pronounced at the ends of the sites of the plates Where the tips of the screws had penetrated the periosteum, sub-periosteal bone had formed a cone around the tips. The radiograms of the cross sections under the midpoint of the internal fixation plates showed increased porosity compared with corresponding sections from the control bones Areas of newly formed periosteal bone

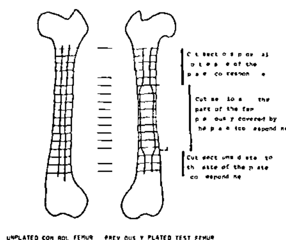


Figure 1 Cut sections of femur in which a rigid internal fixation plate (AOI-type) has been applied for 7 months and of the corresponding control femur not affected by a plate

Table 1 The mean values of the total areas [illegible]

and from the seven control femora The areas are given in relative numbers The deviation of the previously plated femora is expressed as a percentage of the corresponding values of the respective control femora

Dog no	Control bone Femur not affected by a rigid plate	Test bone Femur affected by a rigid plate	Percentage deviation
1	352	353	−0 3
2	327	321	1 8
3	324	319	1 5
4	272	272	0 0
5	319	322	−0 9
6	300	297	1 0
7	303	298	1 6

The areas of the cross sections had not decreased under the site of the plate (mean = 0 67 per cent, S D = 1 06) Paired observation tests t = 1 63, $P > 0\ 05$

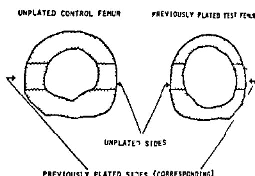


Figure 2 Standard partial cortical areas of cortical cross section from femur in which an internal fixation plate (AOI type) has been applied for 7 months and the analogous areas of the corresponding control femur

were observed on both the test and control bones

Planimetry of the total cross sectional areas of the bones, including the marrow cavity under the sites of the plates, displayed no significant reduction compared with the corresponding areas from the previously non plated control bones (Table 1, Figure 1 Figure 2)

The cortical areas of the cross sections of those parts of the bones which had been covered by the plates showed a significant reduction as compared with the contralateral control cross sections (Table 2a, Figure 1 Figure 2)

The cortical cross-sectional areas on the plated side of the stabilized femora, excluding the periosteal formed bone, were not reduced in comparison with the opposite side of the same bone (Tables 3a, 3b, Figure 2)

There was however a pronounced enlargement of the medullary cavities of that part of the test bones previously covered by the plate compared with those of the control bones (Table 4, Figure 1, Figure 2)

The cortical cross-sectional areas proximal and distal to the sites of the plates showed no

Table 2 The mean values of parts of the cross-sectional areas representing the cortical bone (Figure 2) from ten cross sections under the site of [illegible] *femora The areas are given in relative numbers The deviation of the previously plated femora is expressed as a percentage of the corresponding values of the respective control femora*

(a) Cross sectional parts (cortical bone) proximal to the site of the plate (Figures 1, 2) (corresponding)

	Control bone	Test bone	
Dog no.	Femur not affected by a rigid plate	Femur affected by a rigid plate	Percentage deviation
1	200	185	−7 5
2	186	180	−3 2
3	181	199	9 9
4	157	187	6 4
5	196	196	0 0
6	154	150	−2 8
7	175	172	−1 7

The areas had not changed proximal to the site of the plate (mean − 0 2 per cent, S D = 5 98) Paired observation tests t − 0 00, $P > 0\ 05$

(b) Cross sectional parts (cortical bone) under the site of the plate (Figures 1, 2) (corresponding).

	Control bone	Test bone	
Dog no	Femur not affected by a rigid plate	Femur affected by a rigid plate	Percentage deviation
1	222	194	−12.6
2	205	176	−14 1
3	197	167	−15 2
4	187	170	−9 2
5	191	174	−18 9
6	201	177	−11 9
7	185	173	−6 5

The areas had decreased under the site of the plate (mean = 11 2 per cent, S D − 3 13) Paired observation tests t = 8 37, $P < 0\ 05$

(c) Cross sectional parts (cortical bone) distal to the site of the plate (Figure 2) (corresponding)

	Control bone	Test bone	
Dog no	Femur not affected by a rigid plate	Femur affected by a rigid plate	Percentage deviation
1	172	182	5 8
2	180	169	−6 1
3	184	197	7 1
4	184	173	5 5
5	187	173	−3 2
6	183	182	−0 5
7	166	181	9 0

The areas had not changed distal to the site of the plate (mean = 2.5 per cent, S D = 5 76). Paired observation tests t = 0 67, $P > 0\ 05$

differences between the test and the control bones (Tables 2a, 2c, Figure 1, Figure 2)

Histological studies of the cortical bone previously covered by the plate showed a uniform distribution of increased osteoblast activity compared with the corresponding contralateral control femora

Furthermore, porosity was most pronounced in the endosteal part of the cortical bone of the test femora Proximal to the site of the plates, there was no difference in porosity between the test and the control bones

Histologically, there was evidence of activity of periosteal bone formation in the previously mentioned ridges close to the internal fixation plates. This activity had, however, ceased in the areas of periosteal bone without connection with the internal fixation plates

The ashing procedure disclosed clearly reduced ash weights of the cross-sectional slices under the plates as compared with those of the control femora (Table 5b) There was no marked difference in the ash weights proximal to the site of the plate and the corresponding part of the control bone (Table 5a)

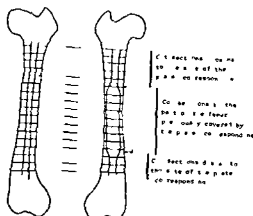


Figure 1 Cut sections of femur in which a rigid internal fixation plate (AOI type) has been applied for 7 months and of the corresponding control femur not affected by a plate

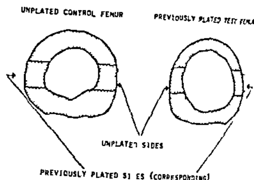


Figure 2 Standard partial cortical areas of cortical cross section from femur in which an internal fixation plate (AOI type) has been applied for 7 months and the analogous areas of the corresponding control femur

Table 1 The mean values of the total areas (cortical bone + bone marrow) (Figure 2) from ten cross sections under the site of the plate (Figure 1) in seven femora to which an internal fixation plate (AOI-type) had been applied for 7 months and from the seven control femora The areas are given in relative numbers The deviation of the previously plated femora is expressed as a percentage of the corresponding values of the respective control femora

	Control bone	Test bone	
Dog no	Femur not affected by a rigid plate	Femur affected by a rigid plate	Percentage deviation
1	352	353	−0 3
2	327	321	1 8
3	324	319	1 5
4	272	272	0 0
5	319	322	−0 9
6	300	297	1 0
7	303	298	1 6

The areas of the cross sections had not decreased under the site of the plate (mean = 0 67 per cent, S D = 1 06) Paired observation tests t = 1 63, $P > 0\ 05$

were observed on both the test and cont bones

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The cortical cross-sectional areas on the plated side of the stabilized femora, excluding the periosteal formed bone, were not reduced in comparison with the opposite side of the same bone (Tables 3a, 3b, Figure 2)

There was however a pronounced enlargement of the medullary cavities of that part of the test bones previously covered by the plate compared with those of the control bones (Table 4, Figure 1, Figure 2)

The cortical cross-sectional areas proximal and distal to the sites of the plates showed no

Table 4 The mean values of the bone marrow areas (Figure 2) from the cross sections under the site of the plate (Figure 1) in seven femora to which an internal fixation plate (AOI-type) had been applied for 7 months and from the seven control femora The areas are given in relative numbers The deviation of the previously plated femora is expressed as a percentage of the corresponding values of the control femora

Dog no	Control bone: Femur not affected by a rigid plate	Test bone: Femur affected by a rigid plate	Percentage deviation
1	130	159	22.3
2	122	145	18 9
3	127	152	19 7
4	85	102	20 0
5	128	148	15 6
6	99	117	18 2
7	118	125	5 9

The areas had increased under the site of the plate (mean = 17 2 per cent, S D – 5 39) Paired observation tests $t = 7\ 47$, $P < 0\ 05$

visualized by the markedly decreased total cross-sectional cortical area.

The diameter of the medullary cavity increased It was not, however, associated with a change in the outer diameter of the test bone This was taken as evidence that the reduction of material occurs in the endosteal parts of the stabilized bone sections in accordance with the results of Akeson et al but in disagreement with the suggestion of Tonino et al (1976)

The weakening of the cortical cylinder, measured as a reduced resistance to bending and torque loads, acting in combination or individually, is thus minimized due to the fact that the reduction takes place in the endosteal parts of the cortical wall

The decrease in bone material asserted itself not only as reduced cortical cross section area, but also in increased porosity The ash weight determinations were in accordance with the decreased bone material content in the stabilized sections This does

Table 5a The mean values of the ash weights from the cut sections proximal to the site of the plate (Figure 1) in seven femora to which an internal fixation plate (AOI type) had been applied for 7 months and from the seven control femora The weights are given in mg The deviation of the previously plated femora is expressed as a percentage of the corresponding values of the control femora

Dog no	Control bone: Femur not affected by a rigid plate	Test bone: Femur affected by a rigid plate	Percentage deviation
1	0 5057	0 5038	0 4
2	0 4510	0 4493	–0 4
3	0 5064	0 4971	–1 8
4	0 4079	0 4261	4 5
5	0 4468	0 4558	2 0
6	0 3746	0 3833	2 3
7	0 4181	0 3989	–4 5

The ash weights had not changed proximal to the site of the plate (mean = 0 3 per cent, S D = 2.98). Paired observation tests $t = 0\ 11$, $P > 0\ 05$

Table 5b The mean values of the ash weights from the cut sections under the site of the plate (Figure 1) in seven femora to which an internal fixation plate (AOI type) had been applied for 7 months and from the seven control femora The weights are given in mg The deviation of the previously plated femora is expressed as a percentage of the corresponding values of the control femora.

Dog no	Control bone: Femur not affected by a rigid plate	Test bone: Femur affected by a rigid plate	Percentage deviation
1	0 5876	0 4848	–16 8
2	0 4172	0 3459	–17 1
3	0 4903	0 4025	–17 9
4	0 4308	0 3808	–11 6
5	0 4134	0 3616	–12 5
6	0 4277	0 3486	–18 5
7	0 5026	0 4166	–17 1

The ash weight had decreased in the part of the bone previously covered by the plate (mean = 15 9 per cent, S D = 2 72) Paired observation tests $t = 10\ 29$, $P < 0\ 05$

not seem to be in full agreement with the observation of Woo et al (1976) that the mechanical changes due to internal fixation plating were a result of reduction in the cortical bone structure by thinning of the cortex rather than a reduction in the mechanical properties of the bone substance

In the present study no increased cross-sectional area or elevated ash weight proximal or distal to the sites of the plates were observed as signs of increased quantity of bone material. This was to be expected as according to mechanical principles there should be increased stress and strain concentrations and, thus, an increased bone formation

In the present experiments, however, the plates were long when compared with plated diaphyseal bones. The non-covered parts of the bones formed rather short mechanical joints, which together with the geometry of these parts probably explains why the bone substance had markedly increased proximal to the site of the plate

The operative procedure with the application of the rigid metallic plate by means of screws will cause compression of the periosteum and the underlying bone There will be damage to the periosteum and this affects the blood flow situation in the cortical bone and may be partly responsible for the formation of woven bone as observed by Matter et al (1974) This woven bone was placed as a reflection of the plate in the cortex immediately covered by the plate. The dynamic process of altering the blood flow in the cortical bone has been discussed (de Marneffe 1957, Göthman 1960, Brookes 1971) However, the cortical bone is able to compensate for the loss of limited periosteal blood flow, and, 7 months after surgery, we could not find any local effects on the cortical bone due to disturbed blood supply

These observations are in accordance with those of other investigators (Akeson et al 1976, Tonino et al 1976, Woo et al 1976), but as mentioned above do not harmonize in this respect with the results reported by Matter et al (1974) or the clinical observations reported by Diel & Mittelmeier (1974) The differences in species and postsurgical observation times are probably the reasons for this discordance between our results and those of Matter et al. (1974).

In contrast to earlier reports we could not demonstrate that the adaption was most pronounced in that portion of the cross section previously covered by a plate Akeson et al. (1976) and Woo et al (1976) in their joint material, and Matter et al. (1974) observed a decreased thickness of the cortical bone under the site of the rigid plate due to an endosteal resorption. The entire section of the long bone and the fastened rigid metallic plate covering the bone section formed the mechanical joint. Thus there was a changed load situation in the whole bone part of the thus formed mechanical joint with decreased stress and strain in the part covered by the plate as well as in the opposite part

Despite the fact that we have excluded the small periosteally formed bone ridges in our cross-sectional area measurements, it is difficult to explain the dissimilarity of the observed cortical atrophy under the plate in our material and that of the previous reports.

The results of the present investigation are in agreement with our earlier findings (Strömberg & Dalén 1976) The decreased amount of bone material, the observed porosity and the reduction of the cortical wall of the bone with unchanged outer diameter are, according to the principles of strength of materials and solid mechanics, consistent with a decreased maximum torque capacity and maximum angle of torsion at torsional tests reported in previous papers.

The histological findings indicated, in this study, an increased osteoblast activity in the test bones compared with the control ones, which would suggest that the reconstruction, i e, the adaption, was not completed after 7 months Furthermore, neither the momentum of the adaption process nor of the following re-adaption process or its mechanism are yet known A diaphyseal fracture in a dog femur is generally considered clinically healed within a shorter period than 7 months when treated

by means of rigid internal plate fixation These facts, together with our previous and present results, indicate the importance of minimizing the period that the internal fixation plate should protect the bone during fracture treatment from loads, as the protection has an ongoing detrimental effect upon the strength qualities of the bone

The use of internal fixation plates made from less rigid materials than stainless steel is reported in the literature (c.f Woo et al 1974, Akeson et al 1976, Woo et al 1976) The aim seems to be to decrease the weakening effect on the stabilized non-fractured part of the bone To attain the desired rigidity of an internal fixation plate, it would be more practical to design a suitable stainless steel plate than to experiment with other materials of less rigidity The elastic modulus of the material from which the plate is made is of minor interest in this respect It is the stiffness of the designed plate that defines the quality of the performed internal fixation. Equal stiffness can be achieved even if the plates are made from different materials Experiments with plates made from weaker materials than stainless steel are thus only of academic interest concerning the influence of the weakening effect on a non-fractured diaphyseal bone

To achieve primary fracture healing, the fracture surfaces must be kept compressed and fixed against each other The fractured limb may be expected to bear loads early during the healing process, and this can be sustained only if a rigid mechanical joint is formed, e g, by means of a rigid plate according to the AO-method Otherwise the conditions for primary bone healing will not exist.

However, the problem remains of when to remove the implants and how to avoid unnecessary deterioration of the cortical bone, thus minimizing the time required for a fractured diaphyseal bone to regain its normal strength and architecture Until this problem is solved, it cannot be considered that the principles of the treatment of fractures by means of rigid internal fixation [illegible] have been fully clarified

REFERENCES

Akeson, W H Woo S L-Y Rutherford L Coutts R D, Gonsalves M & Amiel D (1976) The effects of rigidity of internal fixation plates on bone remodeling *Acta orthop scand* **47**, 241–249

Basset, C A L (1971) Biophysical principles [illegible] *and* [illegible] New

Brookes, M [illegible] *bone* Butterworth London

Burstein, A H, Currey J Frankel H U Lunseth, P & Vessely, J (1972) Bone strength The effect of screw holes *J Bone Jt Surg* **54** A, 143–156

de Marneffe, R (1957) *Recherches morphologiques experimentales sur la vascularisation osseuse* Edition Acta Medica Belgica Bruxelles.

Diel K & Mittelmeier H (1974) Biomechanische Untersuchungen zur Erklarung der Spongiosierung bei der Plattenosteosynthese *Z Orthop* **112**, 235–243

Gothman, L (1960) The normal arterial pattern of the rabbit's tibia *Acta chir scand* **120**, 201 210

Matter P, Brenwald J & Perren S M (1974) Biologische Reaktion des Knochens auf Osteosynthesplatten *Helv chir Acta*, Suppl 12

Muller, M E, Allgower M & Willenegger H (1970) *Manual of internal fixation.* Springer Verlag Berlin Heidelberg New York

Olerud, S & Lorenzi, G L (1970) Triple fluorochrome labeling in bone formation and bone resorption *J Bone Jt Surg* **52** A 274–278

Pauwels, F (1973) Kurzen Uberblick uber die mechanische Beanspruchung des Knochens und ihre Bedeutung fur die funktionelle Anpassung *Z Orthop* **111**, 681–705

Richon, A, Livio, J J & Saegesser F (1976) Les refractures après osteosynthesis par plaque à compression *Helv chir Acta* **34**, 49–62

Str [illegible]

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The operative procedure with the application of the rigid metallic plate by means of screws will cause compression of the periosteum and the underlying bone There will be damage to the periosteum and this affects the blood flow situation in the cortical bone and may be partly responsible for the formation of woven bone as observed by Matter et al (1974) This woven bone was placed as a reflection of the plate in the cortex immediately covered by the plate The dynamic process of altering the blood flow in the cortical bone has been discussed (de Marneffe 1957, Gothman 1960, Brookes 1971) However, the cortical bone is able to compensate for the loss of limited periosteal blood flow, and, 7 months after surgery, we could not find any local effects on the cortical bone due to disturbed blood supply

These observations are in accordance with those of other investigators (Akeson et al 1976, Tonino et al 1976, Woo et al 1976), but as mentioned above do not harmonize in this respect with the results reported by Matter et al (1974) or the clinical observations reported by Diel & Mittelmeier (1974) The differences in species and postsurgical observation times are probably the reasons for this discordance between our results and those of Matter et al (1974)

In contrast to earlier reports we could not demonstrate that the adaption was most pronounced in that portion of the cross section previously covered by a plate Akeson et al (1976) and Woo et al (1976) in their joint material, and Matter et al (1974), observed a decreased thickness of the cortical bone under the site of the rigid plate due to an endosteal resorption The entire section of the long bone and the fastened rigid metallic plate covering the bone section formed the mechanical joint Thus there was a changed load situation in the whole bone part of the thus formed mechanical joint with decreased stress and strain in the part covered by the plate as well as in the opposite part

Despite the fact that we have excluded the small periosteally formed bone ridges in our cross-sectional area measurements it is difficult to explain the dissimilarity of the observed cortical atrophy under the plate in our material and that of the previous reports

The results of the present investigation are in agreement with our earlier findings (Stromberg & Dalén 1976) The decreased amount of bone material, the observed porosity and the reduction of the cortical wall of the bone with unchanged outer diameter are, according to the principles of strength of materials and solid mechanics consistent with a decreased maximum torque capacity and maximum angle of torsion at torsional tests reported in previous papers

The histological findings indicated, in this study, an increased osteoblast activity in the test bones compared with the control ones, which would suggest that the reconstruction, i e, the adaption, was not completed after 7 months Furthermore, neither the momentum of the adaption process nor of the following re-adaption process or its mechanism are yet known A diaphyseal fracture in a dog femur is generally considered clinically healed within a shorter period than 7 months when treated

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INTRACARDIAL ARTERIOGRAPHIC STUDY ON VASCULAR CHANGES IN AMPUTATED RABBITS

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The vascular changes in rabbits after amputation were stud ed *in vivo* with *arteriography after intracardial injection of contrast In the amputated* extremity an initial vasoconstriction of the arteries was found Thereafter changes were observed in arteries and veins, both in the operated and contralateral extremities depending on the level of amputation and the manner in which the stump was closed After amputation distally on the extremity and after stump closure without myoplasty arteriovenous shunting was observed in the amputation stump Arteriovenous shunts were not seen after knee disarticulation and after proximal amputation on crus with myoplasty Inactivity of the muscles in the amputation stump is supposed to be the cause of the shunt formation After mid femur amputa tion a permanent vasoconstriction of the femoral artery was observed whereas artery dilation was seen when amputation on the femur was combined with plugging of the medullary cavity

Key words amputation level arteriovenous shunt closure of the medullary cavity intracardial arteriography vascular changes in amputated rabbits

Accepted 26 ii 78

Previous studies of vascular changes which place after amputation have been based efly on arteriography Increased vas arization in the amputation stump has observed in both clinical and ex imental investigations, but no unequivocal in the diameter of the related arteries been demonstrated Hulth & Olerud (1962) and Langhagel (1968) reported arterial diameters. Erikson & (1966) and Hansen Leth & Reimann (1972) observed transient dilation whilst asse et al (1960) and Erikson (1965) found in diameter The reason for these s in vessel diameter is not clearly un Hasse et al suggested that reduced es resulted from decreased blood circula in the amputation stump whereas found no relationship between degree of dilation and magnitude of blood flow After amputation on rabbits Hansen Leth (1976) observed an increased muscle blood flow in the stump which was dependent on the level of amputation and on the manner in which the marrow cavity was closed

In this experimental study in vivo arterio-graphy on rabbits has been used to determine the vascular changes after amputation and to explain the way in which the amputation level and the method of stump closure influence the vascularization in the amputa tion stump

MATERIAL AND METHODS

Thirty two adult rabbits, weighing 3–4 kg had their left hind leg amputated under Nembutal anaesthesia In 21 animals amputation was

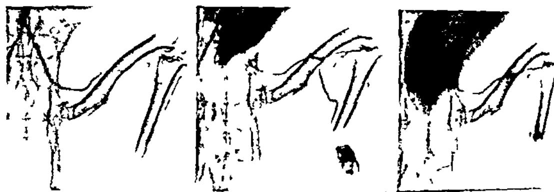


Figure 1 Arteriograms (a) Preoperatively, (b) immediately after fracture on the crus, and (c) immediately after subsequent amputation

performed on the crus, in 5 cases distally and in 16 proximally, at the level of the tibiofibular synostosis. *In the proximally amputated animals the* marrow cavity was left open in four and closed with myoplasty in seven and in a further five myoplasty was combined with osseous plugging of the marrow cavity Disarticulation of the knee joint was carried out in six animals – three of these had been subjected to amputation of the crus prior to the disarticulation Femur amputation was performed on eight animals, three with distal amputation without myoplasty – two of these had been subjected to amputation of the crus prior to amputation on the femur – and five with mid-thigh amputation, two with myoplastic closure and three with myoplasty combined with osseous plugging of the marrow cavity In two animals the crura were fractured prior to amputation and the immediate arteriographic changes after fracture were investigated Two animals died, unoperated, in relation to arteriography

Arteriography was carried out while the animals were under Nembutal anaesthesia The animals were placed supine on the AOT – film changer Seventy-six per cent Urographin was injected intracardially with a lumbar needle (90 x 0 9 mm) inserted through the skin at the tip of the xiphoid process and thrust into the heart The needle was kept open with heparin saline solution and a bolus of 8 cm³ contrast was injected manually during a period of 1–1 5 seconds Six pictures were taken with one exposure every 2 seconds These clearly portrayed the arterial and venous circulations, and permitted estimations of the flow rate (transit time) The degree of change in arterial diameter was measured on subtraction films at cor-

striped ruler placed across the pelvic area of the rabbit)

In all, 70 arteriographs were taken, seven preoperative and 63 within periods of from 1 hour to *130 days*, postoperatively, *One animal was arterio*graphed 8 times, one 6 times, two 4 times five 3 times, ten twice and thirteen once

RESULTS

On the preoperative arteriographs only the larger arteries were contrast-filled, the crural arteries were thread-like, none or only a few veins were seen and vein filling was late in appearance

Arteriographs immediately after amputation disclosed a vasospasm in the amputation stump in contrast to the vasodilation immediately after a closed fracture (Figure 1). Two or four days after amputation on the crus the arteries to the stump were seen to be dilated, dependent on the closure of the *stump and the amputation level*

Table 1 illustrates the contrast passage through arteries and veins (transit time). Early appearance of veins were seen ½–1 week after *distal amputation with myoplasty* as well as after *proximal crus amputation without myoplasty* This happened simultaneously with dilation of the arteries and there was a considerable formation of new vessels in the amputation stump A similar dilation of arteries and rapid filling of veins occurred in the contralateral extremity (Figures 2, 3), but no contralateral vein filling was seen if a tourniquet was applied distally on the contralateral crus.

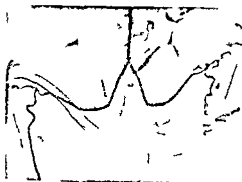


Figure 2 Arteriogram 2 seconds after the injection 32 days after amputation without myoplasty



Figure 3 The same rabbit as in Figure 2 Four seconds later Note the filling of the superficial veins

Table 1 The rate of contrast passage (transit time) in the arteries and veins in the amputation stump One sign means one picture — 2 seconds

TRANSIT-TIME

OPERATION	1 HOUR	1/2 WEEK	1 WEEK	2 3 WEEKS	4 5 WEEKS	6 7 WEEKS	>10 WEEKS
AMP DISTALLY ON CRUS MYOPLASTY	xxxxx	xxxxx xx ooo	xxxxx xxx ΔΔ	xx ooo	xx ●●●●	xxxxx	xxxxx ●●●●●
AMP PROX ON CRUS MYOPLASTY	xx xx	xxx xx ooooo	xx ●●●● xx ΔΔ	xx ΔΔΔ	xx ●●●●● xx ●●●●●	xx ●●●● xx ●●●●●	
AMP PROX ON CRUS MYOPLASTY	xx xxx	xx xxx	x xx	xx ΔΔΔΔ xx ΔΔΔ	xxxx	xxxxx	
AMP PROX ON CRUS PLUGGING	xx	xx	xxxxx xxx ΔΔΔ	xxxx oooo	xxx ●●● xx oo	xx ooo	xxxxx xxxxx ●●●
EXARTICULATIO GENU	xx	xx	xx ΔΔΔ	xx ΔΔ xx Δ	xxxxx ΔΔ xxxxx ΔΔ		xxxxx
AMP DISTALLY ON FEMUR			xx ooo	xx ooo	xx oo	xx	xx ooo

x ARTERY OCCURRENCE
Δ VEIN SLIGHT OCCURRENCE
o VEIN MODERATE OCCURRENCE
● VEIN MARKED OCCURRENCE

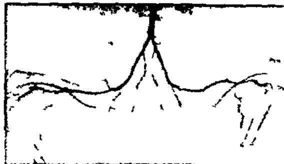


Figure 4 Twenty days after amputation with myoplasty Six seconds after the injection

These findings indicate that arteriovenous shunting takes place in the amputation stump and distally in the contralateral extremity After *proximal crus amputation without myoplasty* the arterial dilation and vein filling in the amputation stump reached a maximum 4–7 weeks after amputation (Table 1)

After *proximal crus amputation with myoplasty* a moderate arterial dilation was observed on the operated side, but only a few newly formed vessels appeared in the stump and 2–3 weeks after operation only a few veins were seen on the operated side (Figure 4) Following proximal *crus amputation with myoplasty and osseous plugging of the marrow cavity* a greater number of vessels appeared in the stump and dilation of related arteries and appearance of veins was seen 2–3 weeks after operation On the operated side the deep veins were observed and on the contralateral extremity the superficial veins (Figure 5)

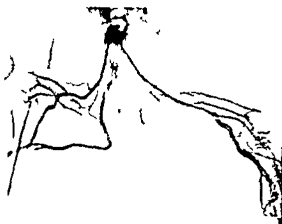


Figure 5 Eighty five days after amputation with osseous plugging and myoplasty Twelve seconds after the injection Note the filling of the deep veins on the left hind leg and superficial veins on the right



Figure 6 Twenty five days after knee disarticulation. The pictures were unchanged throughout the arteriography

After *knee disarticulation* there was reduced filling of the popliteal artery and of the distal part of the femoral artery on the operated side and only a few newly formed vessels appeared in the femur (Figure 6). When knee disarticulation was combined with resection of the distal femoral condyle with detachment of the muscle fixation and opening up of the marrow cavity (*distal femur amputation without myoplasty*), dilation of the femoral artery all the way to the tip of the amputation stump was observed after 1 week and the arterial blood



Figure 7 Twenty days after distal amputation on the femur Two seconds after the injection

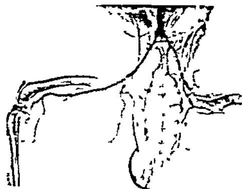


Figure 8 Eighty days after amputation on the femur Four seconds after the injection



Figure 9 Thirty-five days after amputation on the femur combined with osseous plugging Note the abundance of arteries and veins compared with Figure 8

flow and the filling of veins were more rapid than after knee disarticulation (Figure 7)

After *amputation* at a more proximal level *on the femur* (Figure 8) the femoral artery on the operated side was occluded at the level of the hip joint, whilst it was dilated on the non-operated side The arterial blood flow was slower than after distal femur amputation, vein filling was late in appearance and only a few veins were seen However, when *femur amputation* was *combined with plugging of the marrow cavity* (Figure 9), a greater number of vessels appeared in the stump and dilation of related arteries and appearance of veins were seen.

DISCUSSION

After intracardial injection of contrast, serial arteriography provided a clear portrayal of the arterial and venous components of the blood circulation of amputated rabbits and by this method the investigation could be repeated at different time intervals on any one animal

Earlier arteriographic investigations of amputated rabbits have not employed the serial exposure method, and the experimental animals were sacrificed in relation to the arteriographic investigations (Hulth & Olerud 1962, Hansen-Leth & Reimann 1972) Erikson & Olerud (1966) performed angiographies according to an experimental method described by Ekholm et al (1964) The rabbits were intravenously injected with Thorotrast and a single exposure was used This permitted the advantages of an *in vivo* study of circulatory changes, but the use of Thorotrast is prohibited nowadays. In these previous investigations the vascular changes in the amputated extremity were examined in relation to the opposite side In the present study we found that vascular changes also occur in the contralateral extremity after amputation This is in agreement with the findings of Hansen-Leth (1976) who, using the $Xenon^{133}$ clearance method, observed changes in the blood flow in the contralateral extremity, related to the amputation level and the treatment of the amputation stump

The present investigation has shown that amputation of the crus, in contrast to closed fracture, provokes an initial constriction of the arteries to the amputation stump This is in agreement with the findings of Erikson & Olerud (1966), who after crus amputation on rabbits with myoplasty observed an initial constriction of arteries and veins, which may be explained by an involuntarily provoked spasm Similarly, measurement of muscle blood flow (Hansen-Leth 1976, 1977) revealed that amputation in rabbits caused an initial reduction in the flow in the amputation stump, whereas the flow in the triceps surae immediately after open fracture of the crus was unchanged

Erikson & Olerud (1966) observed dilation of the arteries and veins in the amputated leg 3 days postoperatively This dilation increased progressively and occasionally persisted for more than 4 months The present investigation has shown that dilation of arteries and occurrence of veins depend on the amputation level and the method of stump closure Dederich (1963) reported that when the marrow cavity was left open venous stasis occurred in the stump, but when closed myoplastically, venous return was improved We found that crus amputation without myoplastic closure brought about abundant vein formation in the stump, whereas no veins appeared in the stump after amputation with myoplastic closure However, the veins were seen to appear at the same time as the artery or immediately after, and veins appeared simultaneously with dilation of the related arteries and considerable formation of new vessels in the amputation stump This means that the occurrence of veins must be due to arteriovenous shunts in the stump and not an expression of venous stasis Erikson (1965) in a clinical investigation found that amputation without myoplastic closure in some cases led to formation of arteriovenous shunts Similarly, Hulth & Olerud (1962) also proposed a shunt effect to be the reason for the more rapid vein filling in the amputated extremity observed after crus amputation in rabbits Similar arteriographic appearances are seen after surgically produced arteriovenous fistulas (Kelly et al 1959, Holman 1968)

It has been demonstrated in the present study that arteriovenous shunting in the amputation stump, as well as in the contralateral extremity, is pronounced after crus amputation without myoplasty The underlying cause could be the inactivity of the muscles in the stump Occurrence of rapid vein filling in the stump was seen ½–1 week after amputation Similarly Hulth & Olerud (1960) found arteriovenous shunting at the end of the first week after experimentally induced muscle inactivity The proposal that the muscle inactivity is chiefly responsible for the vascular changes is supported by a comparison of the results of knee disarticulation and femur amputation just proximal to the femoral condyle with release of the femoral muscles After knee disarticulation the diameter of the femoral artery was reduced and only a few veins appeared, whereas after condyle resection the femoral artery was dilated all the way to the tip of the amputation stump, and there was a more rapid appearance and abundant filling of veins. However, the arteriovenous shunting after distal femur amputation is less than after amputation on the crus, and after amputation at the mid-femur level no signs of arteriovenous shunts were seen The femoral artery was occluded at the point where it joins with the circumflex femoral arteries Erikson (1965) also found that arteriovenous shunts appeared more frequently after crus amputation than after femur amputation and he observed a greater reduction in artery diameter after femur amputation than after amputation on the crus Similarly, measurements of muscle blood flow (Hansen-Leth 1977) showed that femur amputation on the rabbit, in contrast to crus amputation caused no increase in blood flow in the amputation stump

Amputation with myoplasty combined with osseous plugging of the marrow cavity in contrast to amputation with myoplastic closure alone, resulted in dilation of related arteries an abundance of vessels in the stump and a greater occurrence of veins in both extremities, after crus amputation as well as after amputation on the femur In a clinical study Langhagel (1968) found a greater number of arteries and veins in the amputation stump after osteomyoplastic closure than after myoplastic closure alone

In previous studies the relationship between muscle blood flow and degree of dilation of related arteries in the stump after amputation is not clearly understood Hasse et al (1960) concluded that reduced diameters in afferent arteries resulted from decreased blood flow whereas Erikson (1965) found no relationship between degree of dilation and

magnitude of blood flow The present investigation shows that the dilation of supplying arteries to the stump resulted from the arteriovenous shunting, and that the degree of dilation cannot be assumed to be directly related to the magnitude of muscle blood flow The increased shunting led to a poorer nutritive circulation in capillaries and minor vessels. Similarly, measurement of muscle blood flow after amputation on rabbits (Hansen-Leth 1976) revealed that myoplastic closure of the stump, preventing muscle inactivity and arteriovenous shunting, improved the muscle blood flow in the amputation stump

REFERENCES

Dederich, R (1963) Plastic treatment of the muscles and bone in amputation surgery *J Bone Jt Surg* 45 B, 60–66

Ekholm, J, Eriksen, U & Skoglund S (1964) An improved method for experimental angiography *Brit J Radiol* 37, 839–843

Erikson, Uno (1965) Circulation in traumatic amputation stumps. *Acta radiol (Stockh)* Suppl. 238.

Erikson, U & Olerud, S (1966) Healing of amputation stumps, with special reference to vascularity and bone *Acta orthop scand* 37, 20–28

Hansen-Leth, C & Reimann, I (1972) Amputation with and without myoplasty on rabbits with special reference to the vascularization *Acta orthop scand* 43, 68–77

Hansen-Leth, C (1976) Muscle blood flow after amputation with special reference to the influence of osseous plugging of the medullary cavity *Acta orthop scand* 47, 613–618

Hansen-Leth, C (1977) Muscle blood flow after amputation with special reference to the influence of the amputation level. *Acta orthop scand* 48, 10–14

Hasse, H M Rau, G & Schoop, W (1960) Angiographische Befunde an Amputationsstumpfen *Z Kreis -Forsch* 49, 326–330

Holman, E (1968) *Abnormal arteriovenous communications, peripheral and intracardiac* [illegible] Ed 2, 245 pp Charles [illegible] 431–435

Kelly, P J, Janes, J M & Peterson, L. F A (1959) The effect of arteriovenous fistulae on the vascular pattern of the femora of immature dogs. *J Bone Jt Surg* 41-A, 1101–1108

Langhagel, J (1968) *Angiographische Untersuchungen der Stumpfdurchblutung bei Beinamputierten. Arbeit und Gesundheit* Georg Thieme Verlag Stuttgart

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RADIOLOGICAL STUDIES OF THE WRIST JOINT AMONG CHAIN SAW OPERATING LUMBERJACKS IN JAPAN

Katsumi Suzuki†, Sadao Takahashi* & Taro Nakagawa*

[illegible]

Radiological changes of the wrist joint among 580 chain saw operators and 90 forestry workers (control) who had never used vibratory tools have been studied In both groups, degeneration in the distal radio-ulnar joint and the lunate bone was recorded as a prominent finding However changes peculiar to chain saw operators or a close relation between those changes found and the number of years spent operating a chain saw could not be found in this study

Key words radiological study, wrist joint, chain saw operator, variant of the ulna

Accepted 14 xii 77

Throughout the world, recent technological developments have become the cause of various occupational disorders In fact, even as early as 1911, there was a report by G Loriga on the relationship between vibratory tools and "white finger" (Miura 1975)

Since 1955, use of the chain saw among Japanese lumberjacks has increased steadily and is now common throughout the country Furthermore, by 1963, the average number of hours which Japanese forestry workers spent daily operating a chain saw had reached five (Miura 1975) In 1970, in an effort to prevent vibration syndrome, this time was limited to 2 hours by National Forestry officials

Radiological changes of the wrist joint among 580 chain saw operators and 90 controls have been under study since 1970

METHOD

For this study, X-ray films of the 670 chain saw operators and controls were examined as shown in Table 1 Standard antero-posterior and lateral exposures of the wrist joint (Kagita 1966) were collected at this clinic and then studied by the authors of this paper

In grading radiological changes, the following numerical expressions were used, 0 to mean normal, 1 corresponding to a slight change and 2 meaning a prominent change The numerical designations of several items, such as bony atrophy, cyst formation spur formation narrowing of the joint space anomaly or subchondral bony sclerosis, were summed up for each joint, the result being the grade of overall radiological degeneration

RESULTS

The age distribution and years spent operating a chain saw were as shown in Table 1

Variants of the ulna were detected in the antero-posterior view If the longitudinal difference between the ulna and the radius in the distal radio-ulnar joint was less than 1 mm, the ulna was classified as a zero variant, if the difference was more than 1 mm, the longer ulna was ranked a plus

variant and the shorter ulna was designated as a minus variant This definition was different from the usual one, as formulated by Hulten (1935)

Of the 670 cases studied, 55 2 percent showed the zero variant, 43 7 percent a plus variant and 1 1 percent a minus variant No differences were found between the right and the left wrist joints, as shown in Table 2

Among the various changes recorded, arthrosis-like changes of the distal radio-ulnar joint were the most remarkable, followed by a cyst formation of the carpal bone, as shown in Figures 1 and 2.

Among the carpal bones, subchondral bony sclerosis and cystic changes were recorded most frequently in the lunate, then in the triquetrum and thirdly in the navicula, as shown in Figures 2 and 3 These changes were particularly common in chain saw operators under the age of 49 with a plus variant.

However, radiological changes of the wrist joint did not increase in accordance with the number of years spent operating chain saws, as shown in Figure 4

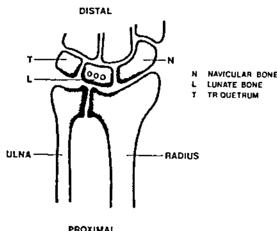


Figure 1 Illustration of radiological changes in A-P view of the wrist joint

DISCUSSION

Nowadays, Japanese forestry workers are mainly in their forties, fifties and sixties Thus, in this study, age-related changes had to be analyzed along with the other radiological changes

Table 1 Age distribution and number of years spent operating chain saws

Years of chain saw operation / Age	20–39	40–49	50–	Total
0–5	7	10	5	22
6–7	17	20	5	42
8–9	19	29	9	57
10–	126	228	105	459
Total	169	287	124	580
Control	20	43	27	90

Table 2 Variant of the ulna (percent in 670 persons)

Left / Right	Plus	Zero	Minus	Total
Plus	34 4	7 7	0	42.1
Zero	10 7	45 2	0 9	56.8
Minus	0 2	0 6	0 3	1 1
Total	45 3	53 5	1 2	100 0

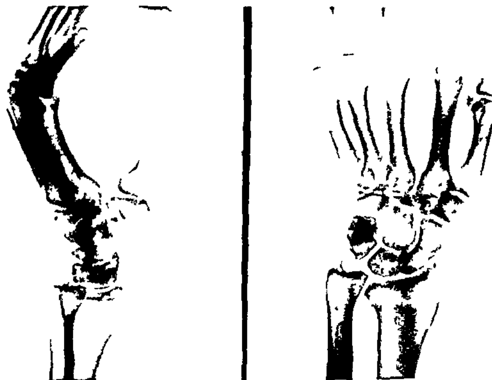


Figure 2 The wrist joint of a chain saw operator (plus variant of the ulna, cystic and sclerotic changes)

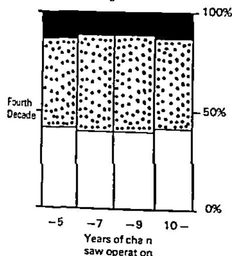
CHAIN SAW OPERATORS — Plus Variant; Zero Variant
CONTROLS — Plus Va ant; Zero Var ant

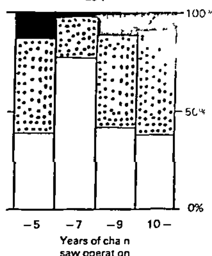
Lunate — 100%, 50, 0; 30–39, 40–49, 50–59 years

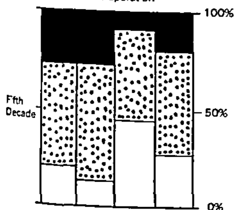
Tr quetrum — 100%, 50, 0; 30–39, 40–49, 50–59 years

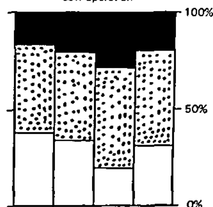
Nav cula — 100%, 50, 0; 30–39, 40–49, 50–59 years

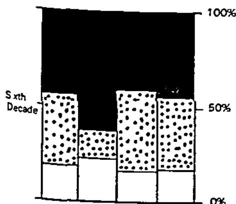
Figure 3 Relation between changes of the carpal bones and age

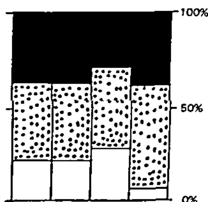












Persons graded more than 8 points

Persons g aded 4 to 7 points

Persons graded 0 to 3 po nts

Figure 4 Radiological changes in the wrist joint related to years of chain saw operation

As regards age-related changes in the wrist joints of Japanese forestry workers, degenerative changes in the distal radio-ulnar joint and the lunate bone were recorded as prominent findings

In previous radiological studies of the wrist joints of chain saw operators (Hellstrom & Andersen 1972 and James et al 1975), the existence of any special occupationally related changes could not be proven

Special changes among chain saw operators or a close relationship between those changes found and the number of years spent operating chain saws could not be found in this study

REFERENCES

Hellstrom B & Andersen K L (1972) Vibration injuries in Norwegian forest workers *Brit J industr Med* 29, 255–263

Hulten, O (1935) Ueber die Entstehung und Behandlung der Lunatummalazie (Morbus Kienboeck) *Acta chir scand* 76, 121 135

James, P B, Yates, J R & Pearson, J C G (1975) An investigation of the prevalence of bone cysts in hands exposed to vibration. *Vibration white finger in industry* ed. Taylor W & Pelmear, P L pp 43–52 Academic Press London

Kagita, M (1966) *Methods of X raying bone and joint* pp 26–27, Kanehara Shuppan Co Tokyo

Miura, T (1975) On the vibration syndrome in Japan due to handheld vibrating tools *Journal of Science of Labour* 51, 771–787

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PREDICTION OF SPIROMETRIC VALUES IN PATIENTS WITH SCOLIOSIS

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The prediction of normal spirometric values requires a measure of the non-deformed body height of scoliotic patients. The arm span method has been used for estimating the non-deformed body height in spite of the fact that

span/height ratio

Multiple regression equations including arm span and age as regressors were used to calculate the non-deformed body height in scoliotic patients.

height and predicted spirometric values that agreed closely with those obtained by the method using the degree of curvature of the spine The two methods may be used alternatively In accordance with earlier reports, the predicted spirometric values were underestimated when the measured body height was used

Key words scoliosis, spirometry

Accepted 8 iii 78

In scoliosis it is important to evaluate the decrease in lung volumes and ventilatory function of the patients as compared with normal conditions. A difficulty is that body height is generally used in prediction formulas for spirometric values It has been pointed out earlier by Bergofsky et al (1959), Hepper et al. (1965), Lindh & Bjure (1975), and others that the scoliotic curvature tends to decrease the body height and so make the predicted normal values falsely low

The most promising methods described for predicting normal spirometric values, corresponding to the non-deformed body height of scoliotic patients, seem to be the arm-span method (Hepper et al. 1965, Johnson & Westgate 1970) and the method of calculating height loss from the lateral curvature of the spine (Lindh & Bjure 1975)

The arm-span method requires the determination of the relationship between arm span and body height of a non-scoliotic reference group Arm-span/height ratios have been determined for several groups of both sexes (cf Hepper et al 1965), but few examinations seem to cover children. In general,

there seems to be a difference between sexes but conflicting results are reported, particularly with regard to children (Engelbach 1932, Hepper et al 1965, Johnson & Westgate 1970)

The present study was undertaken to examine the arm-span/height relationships of a homogeneously examined Swedish reference group covering both sexes and a wide age range, the purpose being to minimize the error of determining the corrected, non-deformed, body height and the predicted normal spirometric values of scoliotic subjects or subjects with other deformities affecting body height Further, it was of interest to compare this method of prediction with the method of Lindh & Bjure (1975) calculating height loss from the lateral curvature of the spine of scoliotic subjects

MATERIAL

A reference group, 91 males and 118 females age range 5–78 years, and mean age 28 years in both groups, with normal body stature at inspection were used for establishing the normal relationships between arm span and body height

Twenty five patients, 21 females and 4 males with idiopathic scoliosis of varying degree were included in this investigation They were between 11 and 25 years of age The vertex of the primary curve of the scoliosis was localized in the thoracic spine The Cobb angle of the primary curvature was 42 (12–82) degrees (mean and range)

METHODS

Arm span was measured on the standing subjects as the distance between the tips of the middle fingers of the maximally extended horizontal arms to the nearest tenth of a centimetre This was done by means of a special device designed for the purpose (Figure 1) The arrangement ensures that the finger tips are at the same horizontal level during the measurements. The error of the method calculated from 19 (12 normal and 7 scoliotic subjects) duplicate measurements performed by different investigators with an interval of 6 hours to 2 days was 0 2 per cent (coefficient of variation of a single measurement) Body height was measured to the nearest tenth of a centimetre on the barefooted subject standing upright

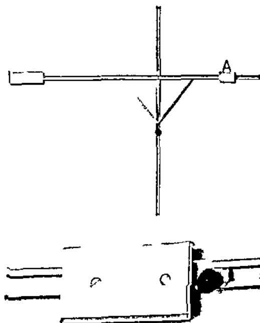


Figure 1 Device for measurement of arm span The level of the horizontal bar can be adjusted to the height of the subject The enlargement shows the part (A) that can be moved along the millimetre scale on the horizontal bar

The angulation of the primary curvature of the scoliotic subjects was measured on frontal roentgenograms according to Cobb (1948). The body height loss of the scoliotic patients was calculated from the angulation of the primary curvature (angle of Cobb) according to the equation given by Lindh & Bjure (1975)

$$\log Y - 0\,011\,X - 0\,177,\ R = 0\,94 \quad \text{(Eqn. 1)}$$

where Y is trunk height loss (cm) and X is the angulation of the curvature (angle of Cobb in degrees) The equation is valid for Cobb angles < 100 degrees (Lindh & Bjure 1975)

Vital capacity (VC) and maximum voluntary ventilation (MVV_{40} and MVV_F) were measured using a Bernstein spirometer (Bernstein et al. 1952) Normal values were predicted according to

Statistical calculations Regression equations were calculated according to the method of least squares. Differences between means were tested using the *t* test (Snedecor 1956)

RESULTS

The mean arm-span/height (AS/H) ratio of the male reference group, 1 029, differed significantly from that of the female reference group, 1 012 ($P<0\ 001$) Our results also indicate that the AS/H ratio in children is lower than in adults The relation between AS/H ratio and age for males and females is shown in Figure 2 The regression equation for males was

$$AS/H = 1\ 013 + 0\ 000556\ A, \quad S_y = 0\ 0215, R = 0\ 45 \text{ (Eqn 2)}$$

and for females

$$AS/H = 0\ 994 + 0\ 000660\ A, \quad S_y = 0\ 0233, R = 0\ 45 \text{ (Eqn 3)}$$

The regression coefficients for age are statistically significant ($P<0\ 001$) S_y is the residual standard deviation

Figure 2 indicates that the relationships are quite linear within the whole age range, 5–78 years.

Equations 2 and 3 make possible a calculation of height from arm span However, we

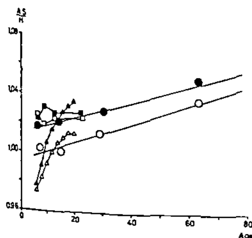


Figure 2 Arm span/height (AS/H) ratio in relation to age (years) for males ●—● *and females,* ○—○ *(cf Eqns 2 and 3) The symbols indicate mean values for age groups 5–9 10–19 20–49 and 50–79 years Males and females from Engelbach's material are symbolized by* ▲—▲ *and* △—△*, respectively, and corresponding groups from Johnson & Westgate's study by* ■—■ *and* □—□.

found it more suitable to calculate height directly from linear multiple regression equations relating height (H cm) (regressand) to arm span (AS cm) and age (A years) (regressors)

The equations were for males ($n=91$)

$$H = 0\ 9329^{***}\ AS - 0\ 0732^{**}\ A + 8\ 64, \quad S_y = 3\ 51, R = 0\ 98 \text{ (Eqn 4)}$$

and for females ($n=118$)

$$H = 0\ 9405^{***}\ AS - 0\ 0846^{***}\ A + 9\ 88, \quad S_y = 3\ 60, R = 0\ 97 \text{ (Eqn 5)}$$

The regression coefficients of equations 4 and 5 were statistically significant (*** indicates $P<0\ 001$, $^{**}0\ 001<P<0\ 01$) Equations 4 and 5 were used to calculate the corrected body height from arm span in the scoliosis patients (cf also Appendix) Division into age classes or use of non-linear statistical models did not appreciably improve the accuracy of prediction of body height.

Prediction of spirometric values

The uncorrected measured body height, the body height calculated from arm span according to equations 4 and 5, and the body height corrected with the aid of equation 1 (Cobb-angle method) were used in the equations for calculating predicted normal values for vital capacity and maximum voluntary ventilation of scoliotic patients.

A comparison between the two methods of calculating the corrected body height of the 25 scoliotic patients, i.e., that using the arm-span measurement and that using the Cobb angle, is shown in Figure 3 The corrected body height obtained with the two methods agreed closely but was on average slightly smaller with the Cobb-angle method (mean *difference 0 4 per cent or 0 7 cm) This is* reflected in the predicted normal values for vital capacity and maximum voluntary ventilation obtained with the two sets of data (Table 1)

The scoliotic patients were divided into two groups. Nine patients with Cobb angles of 50 degrees or more (mean 61° 9, range

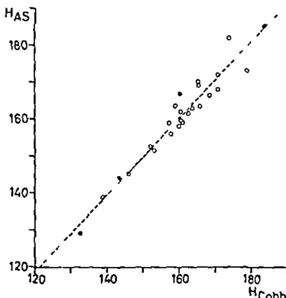


Figure 3 Body height (cm) of 25 scoliotic patients corrected by the method of Lindh & Bjure (1975), H_{Cobb}, *and by Eqns 4 and 5 of the present paper,* H_{AS} ● *= males,* ○ *= females The thin continuous line is the identity line The dotted line corresponds to the linear regression equation fitting the results,* $H_{AS} = 1\ 052\ H_{Cobb} - 7\ 65$, $S_y = 3\ 29$, $R = 0\ 97$

53–82°) formed group A, and 16 patients with an angle of less than 50 degrees (mean 30° 9, range 12–46°) formed group B In both groups the mean values of vital capacity and maximum voluntary ventilation in per cent of predicted normal values were almost the same with the Cobb-angle method and the arm-span method of correction Higher spirometric values in per cent of predicted normal values were obtained when using the uncorrected body height than when using the body height predicted from the arm-span or the Cobb-angle method ($P < 0\ 01$)

DISCUSSION

In conformity with earlier authors, the results indicate that the use of measured body height for predicting lung volumes and ventilatory capacity in scoliotic patients gives an underestimate of the functional disturbance A

Table 1 Vital capacity and maximum voluntary ventilation in per cent of predicted normal values (VC % and MVV %) of two groups of scoliotic patients

	Group A $n=9$	Group B $n=16$
VC %, calculated from		
Measured H	79	80
H corrected by the Cobb-angle method	75	78
H calculated from arm span	75	77
MVV_{40} %, calculated from		
Measured H	86	85
H corrected by the Cobb-angle method	83	83
H calculated from arm span	83	82
MVV_F %, calculated from		
Measured H	80	77
H corrected by the Cobb-angle method	77	75
H calculated from arm span	77	74

In group A the Cobb angle of the primary curvature was > 50 (53–82) degrees, in group B it was < 50 (12–46) degrees, mean (range) The normal values of VC and MVV were calculated according to Berglund et al (1963), Birath et al (1963) and Grimby & Soderholm (1963) for adults, and according to Bjure (1963) for children using (1) the measured standing body height (H) (2) H corrected according to Lindh & Bjure (1975), and (3) H calculated from arm span (Eqns 4 and 5)

correction of the body height is therefore warranted

The arm-span method of estimating the non-deformed body height of scoliotic patients has had the disadvantage that the relationship between arm span and body height has not been well defined Some earlier investigators have reported different arm-span/height ratios for males and females (Hepper et al 1965) as well as for different age groups (Engelbach 1932) Some investigators use the same arm-span/height ratio independent of age (Hepper et al 1965), while the results of Johnson & Westgate (1970) indicate that the arm-span/height ratio is independent of both age and sex

Divergences of opinion with regard to the arm span/height ratio seem to be particularly large for the younger age groups (below 20 years of age) These age groups are particularly important, because they correspond to the ages in which idiopathic scoliosis most frequently first appears However, the reference group covers a wider age range and makes the arm span method applicable also in the case of body deformities affecting older subjects.

Our results for the arm-span/height ratio fall between those of Johnson & Westgate (1970) and Engelbach (1932) (see Figure 2) Differences in the populations and the time periods of collecting the data indicate that racial differences or secular changes have contributed to the different results of the examinations.

Our results for the age groups above 19 years of age agree fairly well with those of Hepper et al. (1965), although these authors assume that the arm span/height ratio is independent of age We have preferred linear multiple regression equations which include the effect of age and sex, in predicting corrected body height from arm span

When applied to scoliotic subjects the method based on arm span for correcting body height might be expected to result in a slight underestimation of corrected height for the following reasons

(1) Because of their scoliosis the scoliotic patients might not hold their shoulders at the same horizontal level during the measurement of arm span This may result in a falsely low value for arm span Thus, if a line through the shoulder joints has a 20 degree angle to the horizontal the arm span will be diminished by about 1 6 per cent, assuming a ratio shoulder (biacromial) width/arm span of 0 21 In most cases the error should be less and this possible divergence from normal arm span caused by the deformity is not large and may be disregarded (cf Hepper et al 1965)

(2) According to Burwell et al. (1977) patients with idiopathic scoliosis have an abnormality of general skeletal growth affecting the trunk and the upper limbs The biacromial width may be small and the upper limbs may be short, particularly on the concave side of the primary spinal curve, in relation to, for example, subischial height However the relative reduction in arm span due to such a growth abnormality seems to be small.

The good agreement between the corrected body height obtained with the arm-span and the Cobb-angle methods indicates that the possible underestimation of corrected body height by the arm-span method is small at least in the range of moderate scoliosis examined Inherent uncertainties of the Cobb-angle method must also be considered

The advantages of the arm-span method are that the measurements can easily be made at the same time as the spirometry and they are not influenced by other factors which may also diminish height (e g, additional curvatures or malformation of the spine, abnormally short legs or amputated legs) The body height calculated by means of the arm-span method may therefore be advantageously used in several types of body stature deformation for prediction of normal values of lung function tests.

The comparatively small difference (in the order of 3–4 per cent in group A) between vital capacity and maximum voluntary ventilation in per cent of values predicted from measured body height and corrected body height by the arm span or the Cobb-angle method, in our group of scoliotic patients, and those obtained by, for example, Hepper et al (1965) and Johnson & Westgate (1970), is explained by the smaller scoliotic curvatures in our group The results agree with those of Sevastikoglou et al (1976) It is therefore particularly important to use the non-deformed body height for prediction of normal spirometric values in cases of severe scoliosis

APPENDIX

Tables for predicting body height (cm) from arm span, AS (cm) and age, A (years) from Eqns. 4 and 5 for males and females.

AS \ A	5	10	20	40	60	80
Males						
100	102	101				
105	106	106				
110	111	111				
115	116	115	115			
120	120	120	119			
125	125	125	124			
130	130	129	129			
135	134	134	133			
140	139	139	138			
145	144	143	143	141	140	138
150	148	148	147	146	144	143
155	153	153	152	150	149	148
160	158	157	156	155	154	152
165	162	162	161	160	158	157
170	167	167	166	164	163	162
175		171	170	169	168	166
180		176	175	174	172	171
185		181	180	178	177	176
190		185	184	183	182	180
195		190	189	188	186	185
200			194	192	191	190
Females						
100	104	103				
105	108	108				
110	113	112	112			
115	118	117	116			
120	122	122	121			
125	127	127	126			
130	132	131	130			
135	136	136	135			
140	141	141	140	138	136	135
145	146	145	145	143	141	139
150	151	150	149	148	146	144
155	155	155	154	152	151	149
160	160	160	159	157	155	154
165		164	163	162	160	158
170		169	168	166	165	163
175		174	173	171	169	168
180		178	177	176	174	172

REFERENCES

Bergofsky, E H , Turino G M & Fishman A P (1959 Cardio-respiratory failure i kyphoscoliosis. *Medicine (Baltimore)* 3[illegible] 263–317

Berglund, E , Birath, G , Bjure, J , Grimby G Kjellmer, I , Sandqvist, L & Soderholm, [illegible] (1963) Spirometric studies in normal subjects I Forced expirograms in subjects between [illegible] and 70 years of age *Acta med scand* 17[illegible] 185–192

Bernstein, L , D'Silva, J L. & Mendel, D (1952) The effect of the rate of breathing on the maximum breathing capacity determined with a new [illegible]

Birath, [illegible] Spi[illegible] Ventilatory capacity tests in adults. *Acta med. scand* 173, 193–198

Bjure, J (1963) Spirometric studies on normal subjects IV Ventilatory capacity in healthy children *Acta paediat scand* 52, 232–240

Burwell, R G , Dangerfield, P H & Vernon C L (1977) Antropometry and scoliosis. *Scoliosis* Ed Zorab, P A Academic Press London.

Cobb, J R (1948) Outline for the study of scoliosis. *Amer Acad Orthop Surg* 5, 261–275

Engelbach, W (1932) *Endocrine medicine* Vol I p 261 C C Thomas, Springfield, Illinois.

Grimby, G & Soderholm, B (1963) Spirometric studies in normal subjects. III Static lung volumes and maximum voluntary ventilation in adults with a note on physical fitness. *Acta med scand* 173, 199–206

Hepper, N G G, Black, L F & Fowler W S (1965) Relationships of lung volume to height and arm span in normal subjects and in patients with spinal deformity *Amer Rev resp Dis* 91, 356–362

Johnson, B E & Westgate, H D (1970) Methods of predicting vital capacity in patients with thoracic scoliosis *J Bone Jt Surg* 52 A, 1433–1439

Lindh, M & Bjure, J (1975) Lung volumes in scoliosis before and after correction by the Harrington instrumentation method *Acta orthop scand* 46, 934–948

Sevastikoglou, J A , Linderholm H & Lindgren, U (1976) Effect of the Milwaukee brace on vital and ventilatory capacity of scoliotic patients. *Acta orthop scand* 47, 540–545

Snedecor, G W (1956) *Statistical methods* Ames, U S A

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SACROCOCCYGEAL AGENESIS

A Report of Four New Cases

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A total of 188 cases of sacral agenesis reported in the English literature are reviewed, and four new cases added In 112 cases where the sex was given 60 were males, (53 per cent) and 52 were females (47 per cent) In 163 cases where clinical details were available, 47 children (26 per cent) had unilateral or bilateral dislocation of the hips, 77 (49 per cent) had unilateral or bilateral club feet and 23 children (17 per cent) had spina bifida deformities. Comments are made on the aetiology the clinical picture and the management.

Key words agenesis agenesia lumbosacral sacrococcygeal sacrum

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Sacral agenesis was first described by Hohl in 1852 Further cases have been reported sporadically in the English literature, many describing accompanying musculoskeletal and visceral abnormalities.

The aim of this paper is to add a further four cases and to analyse the incidence of accompanying malformations. Comments are made on the relation of the condition to maternal diabetes, the clinical picture and the aims of management. Table 1 records chronologically the previously reported cases, the sex and the accompanying congenital malformations.

CASE REPORTS

Case 1 A baby girl (T.D) was born on 7 5 73 to healthy parents there being no family history of diabetes.

She was noted to have a barrel-shaped chest, atrophic calves and bilateral club-feet (Figure 1) Radiographs (Figure 2) demonstrated absence of the fourth and fifth lumbar vertebrae, sacral agenesis and congenital dislocation of the right hip

Her club-feet were treated by strapping for 6 weeks and at the age of 4 years they are normal. The congenital dislocation of the right hip was treated initially by an Aberdeen splint, but it did not reduce Open reduction and de-rotation osteotomy were performed at the age of 18 months followed by a Salter's osteotomy at the age of 3½ years. At the age of 4 years she walks with a slight limp. She is continent of faeces but still suffers from precipitancy of micturition. She attends a normal school.

Case 2 A baby girl (S.M) was born on 28 5 73 to healthy parents the mother had no previous miscarriages. There were no virus infections during the pregnancy and there was no history of diabetes in the family

She was noted to have bilateral dislocation of the hips and bilateral club-feet with marked atrophy of both calves.

Radiographs (Figure 3) demonstrated sacral agenesis, absent of the fifth lumbar vertebra and spina bifida of the fourth lumbar vertebra. The lumbar spine was interposed between the two iliac bones to replace the absent sacrum. An intravenous pylogram (IVP) examination showed a single pelvic kidney

Treatment of the club-feet and congenital dis-

Table 1 Cases of sacral agenesis reported, the sex and the accompanying congenital malformations

Year	Author	No of cases	Sex	C D H bilat or unilat	T E V bilat or unilat	Spina bifida	Visceral abnormalities
1852	Hohl	1					
1859	Wertheim	1					
1884	Litzman	1	F				
1889	Albert	1					
1910	Mally	1		1	1		
1910	Friedel	1			1		
1910	Fitch	1					
1911	White	1			1	1	
1913	Charlier & Sauti	1					
1913	Rendy	1		1	1		
1921	Elmslie	1	M	1	1		
1923	Bradburn	1					
1924	Stewart	1			1		
1924	Desfosses & Mouchet	1			1		
1924	Foix & Hilleman	1					
1925	Leri & Linossier	1	F		1		
1927	Drehmann	1			1		
1929	Brack	1					
1931	Feller & Srwenbern	1			1	1	
			M	1	1		
1935	Hamsa	2					
			M	1			
1935	Girard	1	F		1		
1935	Barros Lima	1					
1935	Keinbock & Zimer	1					
1936	Arauzo	1					
1936	Lamoot & Graux	1	F				
1936	Muller	1	M	1	1		
1937	Hilgenreiner	1		1	1		
			M				
1938	Pouzet	2					
			M	1	1		
			?				
1940	Zeligs	2					
			F		1		
1941	Feller & Sternberg	1			1		
1945	Berman	1	F				
1947	Litcher	1	F		1	1	
1950	Freeman	1	M				
			F				
1951	Del Duca et al	2					
			M	1	1		
1953	Katz	1	M		1		
1953	Soothill	1	M		1		
1957	Williams & Nixon	51		1	5		43
			M		1		
1957	Pirkey & Purcell	2					
			M		1		
			M 27				
1959	Blumel et al	50		18	27	14	8
			F 23				
1961	Dassel	1	F		1		

Table 1—cont

Year	Author	No of cases	Sex	C D H bilat or unilat.	T E V bilat or unilat	Spina bifida	Visceral abnormalities
1963	Russell & Aitken	5	F 1, M 4				
1967	Frantz & Aitken	3			3		
1969	Banta & Nichols	7	F 4, M 3	4	4	1	
1971	Rosenfelder	24	F 12, M 12	8	12	6	
1976	Abraham	1	M	1	1		
1977	Dounis	4	F 3, M 1	3	4	2	2

location of the hips was abandoned after 2 months because of severe mental retardation The patient remains in a hospital for mentally subnormal children.

Case 3 A boy (A.E) was born on 14 4 68 to healthy parents The mother did not suffer from any virus infections during the pregnancy and there was no history of diabetes in the family The child was born with severe kyphoscoliosis, bilateral club-feet and flail legs. Radiographs demonstrated sacral agenesis, multiple hemi-vertebrae and subluxation at the left hip The exact level of the agenesis was impossible to determine because of the kyphoscoliosis and pelvic tilt. An IVP demonstrated fused kidneys.

All attempts at corrective treatment were abandoned after a short time because of the flail legs Although incontinent of urine and faeces he attends normal school and manages using a wheelchair and orthotic devices.

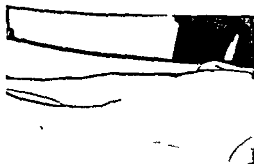


Figure 1 Barrel shape chest and atrophic calves (Case 1)

Case 4 A baby girl (J M) was born on 3 8 71 to healthy parents with no family history of diabetes She attended an orthopaedic clinic at the age of 5 years, having suffered progressive cavovarus deformity of both feet over a period of 2 years. She was noted to have atrophy of both calves and radiographs demonstrated sacral agenesis below the level of the second sacral vertebra (Figure 4) At the present time she is undergoing surgery for correction of foot deformities.

DISCUSSION

There have been a number of theories concerning the aetiology of malformations and absence of the caudal part of the spine A family history has been reported in only one case, a father and son (Pouzet 1938) Maternal diabetes may also be a significant aetiological factor In the 192 cases described in the literature, 16 diabetic mothers have been reported (8 33 per cent), and this incidence may be even higher as many did not record the health of the parents.

It has further been suggested that insulin injections may have a teratogenic effect on the embryo This view has been supported by

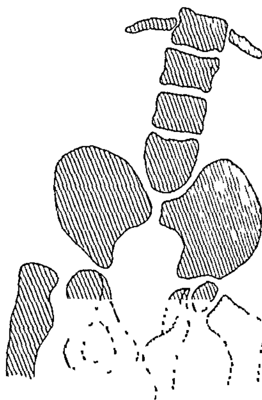



Figure 2 Absence of the lower two lumbar vertebrae and sacrum with apposition of the iliac bones (Case 1)

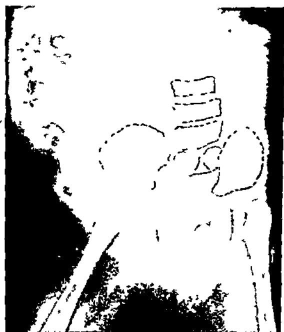
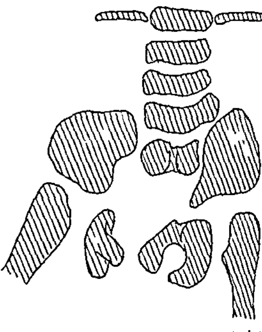



Figure 3 Spina bifida of the fourth lumbar vertebra and absence of the sacrum and fifth lumbar vertebra The lumbar spine is interposed between the iliac bones (Case 2)

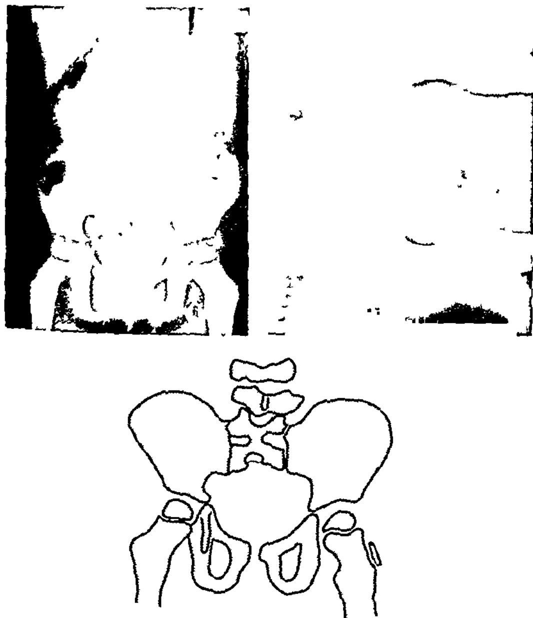


Figure 4 X-ray and tomography show partial absence of the sacrum (Case 4)

Duraiswami (1950) who has experimentally produced caudal depression in chickens by injecting insulin into the eggs He excluded trauma as a cause, since inactivate insulin or normal saline injections produced no deformity

The typical clinical picture is of a child with a barrel-shaped chest contrasting with narrow and flattened buttocks and shortened intergluteal cleft The lumbar lordosis is normally absent, although there may be prominence of the lower lumbar spine (Figure 1) The legs are cone-shaped due to atrophic or absent calf muscles. The pelvic ring is completed with either direct apposition of the iliac bones or with interposition of the lum-

bar spine replacing the absent sacrum (Figures 2, 3) Scoliosis occasionally occurs and is in some cases, paralytic or due to hemivertebrae Visceral abnormalities such as anal atrasia, fused kidneys and congenital heart malformations are not uncommon

The management of these cases is symptomatic for each system, and the treatment should start as soon as possible

ACKNOWLEDGEMENTS

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REFERENCES

Abraham, E (1976) Lumbosacral coccygeal agenesis *J Bone Jt Surg* 58 A 1169–1170
Addison J (1955) Sacro-coccygeal agenesis *Proc roy Soc Med* 48, 163–164
Blumel J Burke Evans E & Eggers, G W N (1959) Partial and complete agenesis or malformation of the sacrum and associated anomalies *J Bone Jt Surg* 41 A 497–517
Danforth C H (1932–33) Artificial and hereditary suppression of sacral vertebrae in the fowl *Proc Soc exp Biol Med* 30, 143–145
Dassel P M (1961) Agenesis of the sacrum and coccyx *Amer J Roentgenol* 85, 697–700
Del Duca V, Vernon Davis E & Barroway J N. (1951) Congenital absence of the sacrum and coccyx *J Bone Jt Surg* 33 A 248–253
Duraiswami P K. (1950) Insulin induced skeletal abnormalities in chickens *Brit med. J* 2 384–390
Elmslie R C (1921) Case of congenital absence of sacrum with associated dislocation of one hip and talipes calcaneo-valgus. *Proc roy Soc Med* 15, 8
Frantz C H & Aitken G T (1967) Complete absence of the lumbar spine and sacrum. *J Bone Jt Surg* 49 A 1531–1540
Freeman B (1950) Congenital absence of the sacrum and coccyx *Brit J Surg* 37 299–303
Girard P M (1935) Congenital absence of sacrum *J Bone Jt Surg* 17, 1062–1064
Hamsa N R (1935) Congenital absence of [illegible]
Engelmann Leipzig
Katz J F (1953) Congenital absence of the sacrum and coccyx. *J Bone Jt Surg* 35 A, 398–402.
Pirkey E L & Purcell J H (1957) Agenesis of lumbosacral vertebrae *Radiology* 69, 726–729
Pouzet F (1938) Les anomalies de development due sacrum *Lyon chir* 35, 371–373
Rosenfelder R (1971) Vertebral agenesis. *Phys Ther* 48, 203–217
Russell W E & Aitken G T (1963) Congenital absence of the sacrum and lumbar vertebrae with prosthetic management *J Bone Jt Surg* 45 A 501–507
Soothill J F (1953–54) Congenital absence of sacrum and coccyx *Guy's Hosp Rep.* 102–103, 87–91
Williams D J & Nixon H H (1957) Agenesis of the sacrum *Surg Gynec Obstet* 105, 84–88

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EDITOR A. ALHO

THE HISTORY OF TREATMENT OF CONGENITAL DISLOCATION OF THE HIP JOINT IN FINLAND

Fabian Langenskiöld Lecture

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THE [illegible] BRAL [illegible] BRAL [illegible]

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Medical care in Finland is carried out at three levels (1) the basic level (local health centres, etc.), (2) the intermediate level (central hospitals), (3) the highest level (university hospitals) The role of the local centres in the care of cerebral palsy (CP) patients concerns early diagnosis and supportive treatment at home The role of the central hospitals involves more advanced follow-up and treatment on an outpatient basis. The university hospitals see to ward treatment (rehabilitation units) and special examinations and treatment, including orthopaedics. At present, there are rehabilitation units in Helsinki and Kuopio.

The consideration of an orthopaedic procedure involves several factors, such as, mental function, developmental stage, treatment of other disturbances (e.g., speech disorders), the nature and severity of the motor abnormality and, especially, adequate scope for preoperative and postoperative treatment. Because a competent team is required in such a consideration, and because a sufficient number of cases is needed to get adequate experience, it is suggested that operations be performed in two or three centres (Helsinki Kuopio, Oulu) The operations should be performed by orthopaedic surgeons in centres with facilities for proper preoperative and postoperative treatment.

THE NEUROLOGICAL MECHANISM OF SPASTICITY

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CP syndromes can be classified as follows *Spastic forms* (hemiplegia, "double" hemiplegia tetraplegia or quadriplegia, and diplegia), *Extrapyramidal forms* (dyskinetic type, dystonic type, ataxia, and tremor), *Mixed forms* (primarily spastic and primarily extrapyramidal)

Orthopaedic treatment is mainly indicated in the spastic forms, which make up 60–80 per cent of all CP syndromes.

The basis of spasticity is a UMN lesion leading to a disturbance in the inhibitory and facilitatory system which normally regulates the muscular tonus via the α and γ neurone system at the muscular-spinal level This disturbance is followed by a muscular imbalance In the lower limb the spasticity is manifested in the extensor muscles, the plantar flexors of the ankle and toes being physiologically extensors, and in the adductors of the hip In the upper limb the spasticity appears in the adductors of the shoulder, the flexors of the elbow, wrist and fingers, and the pronators of the forearm From the orthopaedic point of view it is important to keep in mind that one cannot essentially change the basic disturbance by a peripheral operation However, one can improve the motor function of a limb by changing the muscular imbalance and by making more normal patterns of movement possible

THE SCOPE OF PHYSIOTHERAPY IN THE TREATMENT OF CP

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When brain damage is diagnosed or even strongly suspected in a newborn or older child

bar spine replacing the absent sacrum (Figures 2, 3) Scoliosis occasionally occurs and is, in some cases, paralytic or due to hemivertebrae Visceral abnormalities such as anal atrasia, fused kidneys and congenital heart malformations are not uncommon

The management of these cases is symptomatic for each system, and the treatment should start as soon as possible.

ACKNOWLEDGEMENTS

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REFERENCES

Abraham, E (1976) Lumbosacral coccygeal agenesis. *J Bone Jt Surg* 58-A, 1169–1170

Addison, J (1955) Sacro-coccygeal agenesis *Proc roy Soc. Med.* 48, 163–164

Blumel, J, Burke Evans, E & Eggers, G W N (1959) Partial and complete agenesis or malformation of the sacrum and associated anomalies. *J Bone Jt Surg* 41-A, 497–517

Danforth, C H (1932–33) Artificial and hereditary suppression of sacral vertebrae in the fowl. *Proc Soc exp Biol Med* 30, 143–145

Dassel, P M (1961) Agenesis of the sacrum and coccyx *Amer J Roentgenol* 85, 697–700

Del Duca, V, Vernon Davis, E. & Barroway, J N (1951) Congenital absence of the sacrum and coccyx *J Bone Jt Surg* 33 A, 248–253

Duraiswami, P K. (1950) Insulin induced skeletal abnormalities in chickens. *Brit med. J* 2, 384–390

Elmslie, R C (1921) Case of congenital absence of sacrum with associated dislocation of one hip and talipes calcaneo-valgus. *Proc. roy Soc. Med* 15, 8

Frantz, C H & Aitken, G T (1967) Complete absence of the lumbar spine and sacrum. *J Bone Jt Surg* 49 A, 1531–1540

Freeman, B (1950) Congenital absence of the sacrum and coccyx. *Brit J Surg* 37, 299–303

Girard, P M (1935) Congenital absence of sacrum *J Bone Jt Surg* 17, 1062–1064

Hamsa, N R (1935) Congenital absence of sacrum *Arch Surg* 30, 647–666

Hohl, A. F (1852) *Zur Pathologie des Beckens I Das schrag ovale Becken* p 61 Wilhelm Engelmann, Leipzig

Katz, J F (1953) Congenital absence of the sacrum and coccyx. *J Bone Jt Surg* 35 A, 398–402

Pirkey, E L & Purcell, J H (1957) Agenesis of lumbosacral vertebrae *Radiology* 69, 726–729

Pouzet, F (1938) Les anomalies de development due sacrum *Lyon chir* 35, 371–373

Rosenfelder, R (1971) Vertebral agenesis. *Phys. Ther* 48, 203–217

Rüssell, W E & Aitken, G T (1963) Congenital absence of the sacrum and lumbar vertebrae with prosthetic management *J Bone Jt Surg* 45-A, 501–507

Soothill, J F (1953–54) Congenital absence of sacrum and coccyx *Guy's Hosp Rep* 102–103, 87–91

Williams, D J & Nixon, H. H (1957) Agenesis of the sacrum *Surg Gynec Obstet* 105, 84–88.

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THE EFFECT OF 1α-HYDROXYCHOLECALCIFEROL ON THE HEALING OF EXPERIMENTAL FRACTURES IN ADULT RATS

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Unilateral tibial fractures were produced in adult, 1 year-old, male Sprague-Dawley rats The animals were then treated for 6 weeks with daily doses of 2.5 μg, 1 25 μg or 0 125 μg 1α-hydroxycholecalciferol (1α-OH-D_3) The aim of the investigation was to study the effect of this treatment on the healing

The healing rate of the fractures increased in all treatment groups as compared with the controls. The water content of the fractured tibias increased in the rats treated with 2 5 μg doses but decreased in the other groups. On the other hand the mineral content increased in the groups treated with 1 25 μg and 0 125 μg doses and decreased in the largest dose group Furthermore the amount of organic material per wet weight increased with the 2 5 μg dose and was mainly unchanged in the other groups The hydrated bone density and the cortical thickness of the tibia increased most significantly in the group treated with 0 125 μg but the trabecular bone area of the periosteal callus did not increase significantly

The conclusion is drawn that treatment with small doses of 1α OH D_3 has a beneficial effect on the healing rate and on the mineralization of the fracture callus, and on cortical bone formation

Key words fracture healing, experimental 1α-hydroxycholecalciferol

Accepted 31 iii 78

Therapeutic doses of Vitamin D promote calcification of bone in rickets and osteomalacia but Compere et al (1939) found that treatment with physiological doses of Vitamin D did not exert any stimulating effect on the osteogenesis or the mineralization of callus in experimental fractures. Beneficial effects of Vitamin D on fracture healing have, however, been reported in other studies (Bors 1927, Collazo et al 1930) Moreover, Vitamin D has been found to stimulate the differentiation of the osteogenic cell layer of the periosteum of the radius in adult guinea-pigs during fracture healing (Grauer 1932) Vitamin D was also found to display a special selective effect on the organic phase of bone healing in rats (Udupa & Prasad 1963) and on the mineralization of autogenous bone grafts in rabbits (Donatelli et al. 1962) and further to accelerate the initial mineralization in fracture repair of rats (Steier et al 1967)

Supported by a grant from the Karolinska Institute

Great advances in the research of the biological functions and metabolism of Vitamin D have taken place in recent years Thus, Vitamin D_3 is known to be hydroxylated in the liver to 25-hydroxycholecalciferol (Ponchon & DeLuca 1969) and further in the kidney to the metabolically active form 1 25-dihydroxycholecalciferol (Fraser & Kodicek 1970) The synthetic analog 1α-hydroxycholecalciferol (Holick et al 1973) which is converted to 1 25-dihydroxycholecalciferol in the organism (DeLuca et al 1976) has been *found to increase the intestinal absorption* of calcium (Peacock et al 1974) and thus secondarily affect bone resorption (Raisz et al 1972) and remodelling

Because the observations made in previous studies on the effect of Vitamin D are inconclusive, and because the dose-related effects of Vitamin D on fracture healing have not been thoroughly examined, the present investigation was undertaken to study the effect of various doses of the synthetic drug 1α-OH-D_3 on healing of experimental fractures in adult rats

MATERIAL

Altogether 75 male adult rats of the Sprague-Dawley strain were used in two different series The rats were about 1-year-old The initial body weight of the animals in the first series was 473 g in the second 538 g All rats received a diet containing about 1 15 per cent calcium, 0 8 per cent phosphorus, and 24 5 per cent protein per dry weight The diet contains an adequate amount of Vitamin D, i e 15 IU Vitamin D_3/10 g diet The animals received food and water *ad libitum*

Five days a week the rats received peroral doses of 1α-OH-D_3 diluted in propylenglycol* The administration of the drug was started after the tibia and fibula were fractured and continued for 6 weeks, after which the animals were sacrificed

The *first series* comprised 30 rats. Thirteen were treated with 2 5 μg 1α-OH-D_3/day which corresponds to a dose of approximately 5 μg/kg body weight The remaining animals were used as untreated controls

The *second series* comprised 45 rats Fifteen rats were treated with 1 25 μg and another fifteen with 0 125 μg 1α OH D_3/day which corresponds to doses of 2 5 μg and 0 25 μg/kg body weight, respectively The remaining animals in this series were used as controls.

* Kindly supplied by Loven Ltd Copenhagen, Denmark

METHODS

The *final body weights* of all rats were recorded. Seventy-two hours before killing 50 mg of Terramycin® was injected into each animal intra peritoneally The rats were sacrificed by bleeding from the femoral artery under ether anaesthesia. Blood was drawn for determination of *total serum calcium* The consolidation of the fracture was tested manually The right fractured tibia was cleaned from the surrounding soft tissues and was subjected to various analyses. Roentgenograms were taken, and the "*tibia score*" representing the cortical bone thickness was measured on the mid shaft of the tibia The whole fractured tibia including the fracture area and the periosteal callus lump was used for determination of *wet and dry weights, hydrated bone density* and *total ash content* according to methods previously described and used in the laboratory (Sevastikoglou 1972).

Five fractured tibias from each group were prepared for histological microradiographic and fluorescence labelling analyses The *histologic* samples were stained with haematoxylin-eosin and cut into 7 μ thick sections after decalcification. The *microradiographs* were prepared after embedding in methylmethacrylate and sawing off about 80 μ thick slices. These samples were also examined for fluorescence labelling under UV-light in a Zeiss microscope For quantitation of trabecular bone mass of the periosteal callus a Zeiss image auto-analyzer was used

The significance of observed differences was computed using the *t* test for non paired experiments

RESULTS

No rats died during the experiment The oral administration of the drug succeeded without difficulty

The *final body weight* of rats treated with 2 5 μg 1α-OH-D_3 showed a significant decrease ($P<0\ 001$) as compared with their initial body weight and with the final weight of the other rats in this series, which did not change significantly (Table I)

The *consolidation of the fracture*, tested

Table 1 Final body weight and serum calcium level in rats treated over a period of 6 weeks with 2 5 μg 1 25 μg and 0 125 μg 1α OH D_3/day, respectively

	Series I		Series II		
	Control rats	Experimental rats (2.5 μg 1α OH-D_3)	Control rats	Experimental rats (1 25 μg 1α-OH D_3)	(0 125 μg 1α-OH D_3)
Final body weight (g)					
n	17	13	15	15	15
y	492	403	535	540	555
sy	23	61	63	15	36
P	—	<0 001	—	> 0 05	> 0 05
Serum calcium mmol/l					
n	8	8	10	10	10
y	2.52	3 25	2 63	2 92	2 68
sy	0 06	0 01	0 08	0 12	0 67
P	—	<0 001	—	<0 001	>0 05

manually at the end of the experiment, gave the following results in rats treated with 2.5 μg 1α OH-D_3 the fracture was stable in 6/13 cases and in the control rats in 3/17 cases. In rats treated with 1 25 μg, 7/15, and those treated with 0 125 μg, 6/15 fractures were stable In the control rats of both treated series stable fractures were found in 4/15 cases.

The *total serum calcium* was significantly increased ($P<0\ 001$) in rats treated with 2.5 μg and 1 25 μg 1α-OH-D_3 while no significant increase in serum calcium was observed in rats treated with 0 125 μg 1α-OH-D_3 as compared with the corresponding values from the control groups of animals (Table 1)

The *wet weight* of the fractured tibia including the callus lump increased in all treated rats, but the increase was significant ($P<0\ 01$) only in rats treated with 2.5 μg of 1α-OH D_3 (Tables 2 and 3)

The *dry weight* of the fractured tibia increased in all treated rats as compared with the controls. A significant increase ($P<0\ 05$) was found in rats treated with 0 125 μg of 1α-OH D_3 (Tables 2 and 3)

The *hydrated bone density* of the fractured tibia increased significantly ($P<0\ 05$) in rats treated with 1 25 μg and 0 125 μg 1α-OH-D_3, respectively (Tables 2 and 3)

The *total ash content* of the fractured tibia increased in all treated rats The increase was significant ($P<0\ 01$) in the rats treated with 0 125 μg of 1α-OH-D_3 (Tables 2 and 3)

The *"tibia score"* increased in all treated rats as compared with the controls. The increase was significant ($P<0\ 05$) in rats treated with 2 5 μg and 0 125 μg 1α-OH-D_3 respectively (Tables 2 and 3)

The *trabecular bone area* of the periosteal callus showed an increase, though not significant, in rats treated with 0 125 μg 1α-OH-D_3 as compared with the controls. The values from rats in the other groups decreased The differences were non significant (Tables 2, 3 and Figure 1)

The *histological* appearance of the callus from rats of different treatment groups and the controls showed no qualitative differences

The *fluorescence labelling* of the osseous callus did not differ between the animals from the various treatment groups and the controls

Table 2 Parameters of fractured tibia in rats treated over a period of 6 weeks with 2 5 µg of 1α OH D_3/day

Series I			
Fractured tibia		Control rats	Experimental rats (2 5 µ 1α-OH D_3)
Wet weight (g)	n	12	8
	y	1 0620	1 3050
	sy	0 1140	0 1940
	P	—	<0 01
Dry weight (g)	n	12	8
	y	0 7910	0 9130
	sy	0 0560	0 1350
	P	—	>0 05
Hydrated bone density (w/v)	n	12	8
	y	1 5146	1 4723
	$s\bar{y}$	0 0460	0 0430
	P	—	>0 05
Total ash content (g)	n	12	8
	y	0 5282	0 5796
	sy	0 0428	0 0807
	P	—	>0 05
'Tibia score' (%)	n	12	8
	y	36 9	40 9
	sy	3 2	5 4
	P	—	<0 05
Trabecular bone area of periosteal callus (%)	n	5	5
	y	23 67	16 64
	sy	12 99	8 04
	P	—	>0 05

DISCUSSION

The present experiments indicated that large doses of 1α-OH-D_3, i e 2 5 µg, produced a significant hypercalcaemia and additionally decreased the body weight of the rats by about 20 per cent This dose and still larger doses probably produce toxic effects in the adult rat Dose levels of 1 25 µg did not significantly affect the body weight but the serum calcium level still increased significantly producing slight hypercalcaemia as compared with the controls Lower dose levels, i e 0 125 µg, did not influence the body weight of the animals and their serum calcium levels rose only slightly, and not significantly, during treatment This low dose level probably does not produce any toxic effects in the adult rat

In addition to these general effects there were also specific alterations in the composition and in the other examined parameters of the fractured tibia and the periosteal callus during treatment with 1α-OH D_3 An acceleration of the consolidation rate of the fracture tested manually was recorded in all treatment groups compared with the controls Furthermore the mineralization of the fractured bone increased as evidenced by the total ash content and by the amount of mineral, expressed as a percentage of the wet weight, when treated with the low dose

Table 3 Parameters of fractured tibia in rats treated over a period of 6 weeks with 1 25 µg and 0 125 µg of 1α-OH-D₃/day, respectively

			Series II	
Fractured tibia		*Control rats*	Experimental rats (1 25 µg 1α OH-D₃)	(0 125 µg 1α-OH-D₃)
Wet weight (g)	n	10	10	10
	ȳ	1 2839	1 3063	1 3812
	sy	0 1521	0 1188	0 1221
	P	—	>0 05	>0 05
Dry weight (g)	n	10	10	10
	y	0 8015	0 8468	0 8831
	sy	0 0783	0 0623	0 0712
	P	—	>0 05	<0 05
Hydrated bone density (w/v)	n	10	10	10
	y	1 4120	1 4450	1 4390
	sy	0 0250	0 0320	0 0240
	P	—	<0 05	<0 05
Total ash content (g)	n	10	10	10
	y	0 4974	0 5330	0 5570
	sy	0 0444	0 0363	0 0463
	P	—	>0 05	<0 01
"Tibia score" (%)	n	15	15	15
	y	44 18	45 92	46 61
	sy	2.88	1 75	2 86
	P	—	>0 05	<0 05
Trabecular bone area of periosteal callus (%)	n	5	5	5
	y	31 50	29 87	32 40
	sy	11 26	14 17	14 74
	P	—	>0 05	>0 05

levels These observations are partly supported by similar results achieved by Vitamin D_2 treatment in which the uptake of ³²P and thus the mineralization rate of the healing of autogenous bone grafts in rabbits was enhanced (Donatelli et al 1962) Furthermore the ash content of the rat callus was observed to increase as a result of Vitamin D_2 treatment (Steier et al 1967)

The effect of 1α OH-D_3 was also an increase in wet and dry weights of the fractured bone indicating an increase of organic matrix components When calculating the amount of water in per cent of wet weight it was noted that there was an increase in water content of the fractured bone treated with 2 5 µg doses In contrast the water percentage diminished in the fractured tibias treated with the other dose levels The organic material expressed as a percentage of the wet weight increased slightly in the group treated with 2.5 µg and was mainly unchanged in the other groups. On the other hand the total dry weight increased significantly in the group treated with 0 125 µg of 1α-OH-D_3 In a previous study it has been observed histologically that Vitamin D_2 accelerates the organic phase of fracture repair (Udupa & Prasad 1963).

At all dose levels of 1α-OH-D_3 the capacity to increase the cortical bone thickness in the tibia adjacent to the fracture was demonstra-



Figure 1 Microradiograph of tibial fractures after 6 weeks treatment with 1α OH D, A = control B = treatment with 0 125 μg dose The differences are small, but the bone trabeculae are stronger in the treated group compared with the control

ted This can probably be seen as an increase in either periosteal or endosteal new bone formation The hydrated bone density, however, decreased when treated with large doses and increased with the lower dose levels The trabecular bone area of the periosteal callus did not increase significantly in the different treatment groups, although at the low dose level, i e 0 125 μg, there was a bone increasing effect

The conclusion drawn from these experiments is that the dose level of 0 125 μg of 1α-OH-D, *can best promote healing of rat* fractures It increases the mineral in fractured bone and enhances the cortical bone mass as well as the periosteal callus without producing hypercalcaemia or significantly affecting the body weight of the animals

This beneficial effect of low doses of 1α-OH-D, may be explained by a direct action on the bone producing cells There is some evidence that metabolites of Vitamin D, may act via physiological protein receptors in bone cells (Kream et al 1977) On the other hand there may be a secondary effect on bone due to the ability of 1α-OH-D, to increase the intestinal absorption rate of calcium (Peacock et al 1974) The increase in the serum calcium level may inactivate the parathyroid glands and thus decrease the activity of the osteoclasts allowing bone forming cells to activate and increase both the mature bone mass and the formation of callus bone

REFERENCES

Bors, E (1927) Vigantol und Frakturheilung *Zbl Chir* **54**, 3266–3269

Collazo, J H, Rubino, P & Varela B (1930) Die Rolle des Vitamin D für Regeneration des Knochengewebes und die Callusbildung bei experimentellen Frakturen *Arch klin Chir* **158**, 214–233

Compere, E L, Hamilton B & Dewar M (1930) The influence of Vitamin D upon bone repair *Surg Gynec Obstet* **68** 878–891

DeLuca, H F, Holick, S A & Holick, M F (1976) The metabolism and function of 1α hydroxyvitamin D, *Calcif Tiss Res* **21** Suppl 128–135

Donatelli, L, Sorrentino L & DiRosa M (1967) Pharmacological research on the mineral metabolism of the bone under repair Methods and results. *Arch Pharmacodyn.* **134**, 265–275

Fraser, D R & Kodicek, E (1970) Unique bio-

synthesis by kidney of a biologically active Vitamin D metabolite. *Nature (Lond)* **228**, 764–766.

rauer, R. C. (1932) The effect of Viosterol on the periosteum in experimental fractures *Arch Surg* **25**, 1035–1054

Holick, M F, Semmler, E J, Schnoes, H K & DeLuca, H F (1973) 1α-hydroxyderivate of Vitamin D_3 a highly potent analog of 1α-25-dihydroxyvitamine D_3 *Science* **180**, 190–191

ream, B E, Jose, M, Yamada, S & DeLuca, H F (1977) A specific high-affinity binding macromolecule for 1 25 Dihydroxyvitamin D_3 in fetal bone *Science* **197**, 1086–1088

eacock, M, Gallagher, J C & Nordin, B E C (1974) Action of 1α-hydroxyvitamin D_3 on calcium absorption and bone resorption in man. *Lancet* ii, 385–389

onchon, G & DeLuca, H F (1969) Metabolites of vitamin D_3 and their biologic activity *J Nutr* **99**, 157–167

Raisz, L G, Trummel, C L, Holick, M F & DeLuca, H F (1972) 1 25-dihydroxycholecaliferol a potent stimulator of bone resorption in tissue culture *Science* **175**, 768–769

Sevastikoglou, J A (1972) Osteoporosis and parathyroid glands. III The effect of prolonged calcium deficiency on the skeleton of thyroparathyroidectomized rat *Clin Orthop* **85**, 177–183

Steier, A, Gedalia, I, Schwarz, A & Rodan, A (1976) Effect of vitamin D_2 and fluoride on experimental bone fracture healing in rats. *J Dent Res* **46**, 675–690

Udupa, K. N & Prasad, G C (1963) Chemical and histochemical studies on the organic constituents of fracture repair in rats. *J Bone Jt Surg* **45-B**, 770–779

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CHANGES IN CALCIUM AND HYDROXYPROLINE CONTENT OF CORTICAL BONE AFTER COMPRESSION AND NEUTRAL PLATE FIXATION

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Calcium and hydroxyproline content of intact rabbit tibio-fibular bone was assayed chemically 1 day to 36 weeks after compression and neutral plate fixation with a 4-hole stainless steel ASIF/DCP plate

During the first three postoperative weeks calcium content of the cortical bone decreased by an almost significant amount ($P < 0.05$) thereafter calcium values remained subnormal but did not differ significantly from initial postoperative values Hydroxyproline content increased steadily throughout the experiment ($P < 0.001$)

The changes in chemical composition of the bone were of the same magnitude after compression and neutral plate fixation The results suggest that the cancellous transformation of cortical bone known to take place under rigid plates reflects an active remodelling process of the bone in which the calcium and hydroxyproline content changes only slightly

Key words bone, bone plates, fracture fixation, calcium hydroxyproline

Accepted 10 iii 78

In the treatment of certain fractures of long bones, compression plate fixation provides considerable stability and enables subsequent closure of the fracture gap by primary fracture healing (Muller et al 1963, Schenk & Willenegger 1964, Olerud & Danckwardt-Lilliestrom 1968) However, while providing conditions conducive to fracture repair, the attachment of rigid plates to cortical bone simultaneously calls forth a structural derangement of the underlying bone Uhthoff & Dubuc (1971) drew attention to the profound cancellous transformation that occurred after plating of osteotomized canine femora, and Gordes et al (1975b) reported similar changes after plate fixation of osteotomized rabbit tibio-fibular bones. Recent reports suggest that the cancellous transformation of plated cortical bone is accompanied by a decrease in the mineral content of the bone Gordes et al (1975a) reported that 24 weeks after rigid plate fixation of rabbit tibio-fibular bones the mineral content, as measured with a gamma ray attenuation technique, had decreased 26 per cent Using a similar technique Stromberg & Dalén (1976) and Tonino et al (1976) also found that the mineral content of intact canine femora had decreased after rigid plating

Contrasting with these observations are those of Schenk & Willenegger (1964) who showed, with a fluorescence labelling technique, that the renewal rate in osteotomized cortical bone increases during primary bone healing Coutts et al (1973), by measuring

the rate of bone formation in canine dog tibia h tetracycline labelling, also observed a rked stimulus to new bone formation in tical bone subjected to compression ting

No figures are available for the chemically-essed content of calcium and collagen in tical bone subjected to rigid plate fixation e aim of this study was to compare, in bit tibio-fibular bone, the effects of com-ession versus neutral plate fixation on the emically determined content of calcium and droxyproline

ATERIAL AND METHODS

erative procedure

rty adult rabbits weighing from 2 400 to 3 850 g re used. Both tibio-fibular bones were exposed rough a straight incision and a stainless steel ur-hole dynamic compression plate (ASIF/DCP) as firmly attached to the anterolateral face of the tact tibia with a specially devised plate holder he plate which was less than half as long as the one was positioned so that its midpoint lay rectly over the tibio-fibular junction On the ght tibia compression was applied between the ost proximal and the most distal screws, with e two middle screws being driven home in a eutral fashion. The entire tubular segment etween the two outermost screws was thus ubjected to compression On the left tibia the ur hole plate was attached without compression ostoperatively, the animals were housed in eparate cages in which they were allowed to ove about freely Seven animals were excluded rom the study because of infection (1) or a fracture nder the plate (6) Fractures of the plated bones ccurred bilaterally in four, in the right tibio-fibular bone in one and in the left in one

A designated number of animals were killed 1 and 3 days, and 1, 3, 6, 12, 18, 24 and 36 weeks after the operation. Tubular sections from the midshaft of the tibio-fibular bone under the plate were taken for chemical analysis.

Chemical analysis

The samples were carefully freed of soft tissue with the periosteum being preserved intact The bone samples were defatted in several changes of acetone and air-dried to a constant weight and then hydrolysed in 6 N hydrochloride acid at 130°C for 3 hours. One portion of the hydrolysate was neutralized with NaOH and used to determine hydroxyproline content. The method described by Pikkarainen (1968) without benzene extraction was used The coefficient of variation of the method was ± 2.7 per cent The remainder of the hydrolysate appropriately diluted was used to determine calcium content with a Unicam SP 90 atomic absorption spectrophotometer (Unicam Instruments Ltd, Cambridge England) calcium was measured in 1 per cent lanthanium chloride

Sixty two samples from 31 animals were analysed successfully, the samples from two animals were excluded because of technical failure The 31 animals were divided into five groups based on when, postoperatively, they were killed 1–3 days postoperatively (6 animals) 1–3 weeks (12 animals), 6–12 weeks (5 animals) 18–24 weeks (5 animals) and 36 weeks (3 animals)

Statistical methods

To test the statistical significance of the differences between the compression plated and neutrally plated bones the paired t test was used t statistics for two means were used to compare the significance of differences among several groups. $P > 0.05$ was taken to be not significant

RESULTS

Table 1 shows the mean calcium and hydroxyproline content for the five groups of animals Figure 1 adds to this the corresponding calcium/hydroxyproline ratios During the first three postoperative weeks, the calcium content of both the compression and neutrally plated bones declined by an almost significant ($P < 0.05$) 10 per cent Thereafter, calcium values remained subnormal in both groups of bones, but the initial postoperative value and that at 36 weeks did not differ significantly In all bones hydroxyproline content increased steadily, the difference between the initial postoperative value and that at 36 weeks being highly significant ($P < 0.001$) Consequently, the ratio of calcium to hydroxyproline gradually declined, until at 36 weeks the decrease in this ratio for both groups of bones was almost significant ($P < 0.05$) At none of the five periods was there any significant difference either in calcium or hydroxy-

proline content or in the calcium/hydroxyproline ratios between the bones plated with compression and those plated with neutral fixation

DISCUSSION

The attachment of a rigid metallic plate to the cortical bone can induce untoward changes in the underlying bone Gördes et al (1975b) observed that during the first 24 weeks after neutral rigid plate fixatic of rabbit tibio-fibular bone cancello transformation was progressive and pr found In our laboratory, the rigid pla fixation of intact rabbit tibio-fibular bo induced similar changes Thirty-six wee after compression plate fixation the frequenc of cavities in cross sections of the tubul bone underneath the plate had increased a fold in neutrally plated bone cancello transformation was of the same magnitu (Slatis et al. 1978)

Table 1 Concentration of calcium and hydroxyproline (mg/g dry weight of bone) in the tibio-fibul bones of 31 rabbits after compression and neutral plate fixation Mean ± s d

Time after plate fixation	No of animals	Calcium		Hydroxyproline	
		Compression	Neutral	Compression	Neutral
1–3 days	6	189 8 ± 20 6	193 5 ± 21 0	21 8 ± 1 1	22 1 ± 0 9
1–3 weeks	12	174 3 ± 12 0	171 6 ± 31 6	22 9 ± 0 7	23 0 ± 0 9
6–12 weeks	5	179 3 ± 19 0	183 1 ± 17 6	23 3 ± 0 8	23 4 ± 0 6
18–24 weeks	5	187 3 ± 16 5	176 2 ± 12.4	24 2 ± 1 6	24 3 ± 1 7
36 weeks	3	176 8 ± 26 4	182 2 ± 6 50	25 4 ± 2 5	24 7 ± 1 8

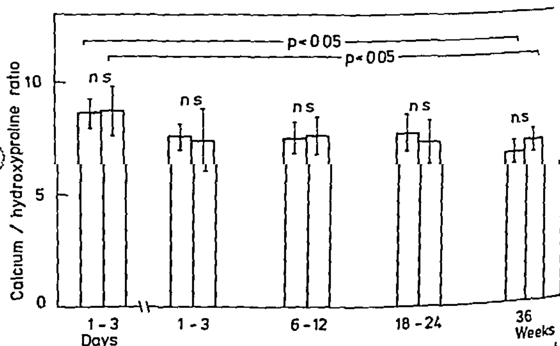


Figure 1 Calcium hydroxyproline ratio in intact rabbit tibio-fibular bone after rigid plate fixation with compression plates (shaded columns) and with neutral plates (white columns) Closed bars represent one standard deviation

Coutts et al (1973) reported no differences ther in porosity or in new-bone formation tween bones plated with and without compression but otherwise plated identically hese authors attributed the observed anges not to compression but to the gidity of the plate Recently, the use of ates with various stiffness properties has own that plates with bending properties osely resembling those of the underlying one bring about less porotic changes in ibular bone than do rigid plates (Tonino et 1976).

During the first 3 weeks of this study the lcium content of all plated bone decreased nd thereafter remained subnormal The ineral loss was less profound than that ported by Gordes et al (1975b) This may e because mineral loss is *greater in the* lated osteotomized bone *these authors* udied *than in plated intact bone* Moreover, e *method* of assaying calcium content may lso *have a* bearing on the estimate arrived Results achieved with the *gamma-ray* tenuation technique are apt *to be influenced* y *changes in bone density* When cancellous ansformation is accompanied by an increase the *amount* of soft tissue elements in the orotic cavities, estimates of *mineral content* nd to be low (Meunier *et* al *1970, Kar*lainen 1973). *Hence, the* continuous decline *mineral content* reported by Gordes et al 1975a) *may* not only reflect a decrease in the mount of mineral in the plated bone, but lso the cancellous *transformation of the* ortical wall adjacent *to the implant* The teady *increase* we observed in the amount of ydroxyproline, together with the corresponding decrease in the calcium-hydroxyproline *ratio*, is evidence of an active turnover collagen – the *prerequisite* for the remodelling of bone *tissue* and for the formation of mmature *new* bone subperiosteally

According to Perren et al (1969), *after* ... the compressive forces *gradually* diminish even *in intact* bone This would mean that at the end of 36 weeks only slight, compressive *forces* were still acting on the ortical bone Our observation that changes in the bones plated with and without compression were similar supports the view that the adverse changes in the plated bone are attributable not to the compression *per se*, but to the effect of the rigid plates.

REFERENCES

Coutts, R D, Harris, W H & Weinberg E H (1973) Compression plating experimental study of the effect on bone formation rates *Acta orthop scand* 44, 256–262

Gordes, W, Kossyk, W & Bodefeld, P (1975a) Versuche zur Kalksalzdichtenbestimmung an der osteotomierten und stabilisierten Tibia des Kaninchens. *Arch orthop Unfall Chir* **81**, *125–147*

Gordes, W, Kossyk, W & Hollander, H (1975b) Histologische und histomorphometrische Veranderungen bei Plattenosteosynthesen nach Osteotomien an der Tibia des Kaninchens *Arch. orthop Unfall-Chir* **82**, 123–133

Karjalainen, P (1973) A method for determination of the mineral content and mineral density of the distal radius using gamma ray attenuation *Ann Clin Res* 5, 231–237

Meunier, P, Aaron, J, Edouard C & Vignon G (1970) Ostéoporose et involution adipeuse de la population cellulaire de la molle *Presse méd* **78**, *531–534*

Muller, M E, Allgower, M & Willenegger, H (1963) *Operative Frakturbehandlung* Springer Verlag, Berlin, Gottingen Heidelberg

Olerud, S & Danckwardt Lillieström, G (1968) Fracture healing in compression osteosynthesis in the dog *J Bone Jt Surg* 50-B 844–851

Perren, S M, Huggler, A Russenberger, M Strauman, F, Muller, M E & Allgower M (1969) A method of measuring the change in compression applied to living cortical bone *Acta orthop scand* Suppl 125 7

Pikkarainen, J (1968) The molecular structures of vertebrae skin collagens. *Acta physiol. scand*, Suppl 309

Schenk, R & Willenegger H (1964) Zur Histologie der primaren Knochenheilung *Langenbecks Arch klin Chir* **308** 440–451

Slatis, P Karaharju, E, Holmström, T, Ahonen, ...

rigid plate for internal fixation on the maximum torque capacity of long bones. *Acta chir scand* **142**, 115–122.

Tonino, A J, Davidson, C L, Klopper, P J & Linclau, L A (1976) Protection from stress in bone and its effects *J Bone Jt Surg* 58-B, 107–113

Uhthoff, H K & Dubuc, F L (1971) Bone structure changes in the dog under rigid internal fixation *Clin Orthop* 81 165–170

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STUDIES ON MECHANICAL STRENGTH OF BONE

I Torsional Strength of Normal Rabbit Tibio-Fibular Bone

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A method is descr [illegible] bones at low velocities. [illegible] the effect of the [illegible] torsional properties are analysed

Rabbit tibio-fibular bones exhibited right to-left differences in energy absorption capacity (up to 10 0 per cent) torsional rigidity (7 1 per cent) torque moment at fracture (6 3 per cent) and angular deformation (5 7 per cent) The scatter in energy absorption was more dependent on differences in angular deformation (strain) than on differences in torque moment (stress) No statistically significant dominance of either side could be observed

The biomechanical properties of the bones were dependent on the body weight of the test animal and the transverse dimensions of the bone but were not influenced by the small variations measured in the chemical composition of normal bone

Key words bone, bone strength chemical composition of bone experimental measurement of bone strength

Accepted 1 vi 78

Bone is a heterogeneous and anisotropic material, its mechanical properties have been investigated extensively For this purpose the bone is usually subjected to pure tensile or compressive forces or a combination of these two as in bending or torsion

Measurement of the torque capacity of tubular bone is a suitable method for investigation of mechanical properties because a torsional load exerts simultaneously tensile, compressive and shear forces each acting in a different plane on the same region of the bone. Torque moment is constant in every section of the specimen tested and the result is not critically dependent on the position of the supports of the specimen, as in the bending test (Brooks et al 1970 Burstein & Frankel 1971)

On the other hand tests on the strength of osseous tissue have revealed a number of features which have to be considered in analysing the results. The results obtained are critically dependent on the rate of loading (McElhaney 1966, Burstein & Frankel 1968, Panjabi et al. 1973), the shape and structure of the test specimen (Dempster & Coleman 1961), the stage of mineralization of the bone (Vose 1962, Currey 1969), the relation between the fibre orientation and the forces acting (Ascenzi & Bonucci 1967, 1968, Vincentelli & Evans 1971) and the effects of the storage and post mortem changes (Sedlin

& Hirsch 1966, Stromberg & Dalen 1976a)

However precise the mechanical equipment used for measurements, biological variations inevitably affect the results Within a single species, differences in mechanical properties have been reported between the right and left paired bones (Puhl et al 1972, White et al 1974, Stromberg & Dalen 1976b)

During the course of studies on the healing of experimental fractures (Paavolainen et al, to be published) the need became evident for a reliable method with which to follow the increase in mechanical strength in healing bone To ensure that the method devised gives valid results the present study was undertaken to investigate the precision and linearity of the torsional testing method and the biological variations which may influence the test results

MATERIALS AND METHODS

Experimental animals

Fifteen healthy rabbits of various ages and of both sexes weighing from 2400 to 4850 g (mean 3275 + 682 g s d) were selected for the investigation

After the animals had been killed with an overdose of sodium pentobarbitone the tibiofibular bones were exarticulated and dissected out, with the periosteum intact Between the various test procedures the bones were kept moist in 0 9 per cent NaCl solution at room temperature

Each left and right bone was loaded until failure with external torsion along the longitudinal axis of the specimen

Measuring equipment

A special apparatus for torsiometry was constructed in collaboration with the Technical Research Centre of Finland (Figure 1).

The proximal end of the bone specimen was held rigidly while the distal end was connected with the rotating head of the torsiometer The torque moment was transmitted to the test specimen at an angular velocity of 3 6 degrees second Progressive deformation of the specimen was produced by turning the rotating head with a number of turns on the driver The deformation was registered with a linear potentiometer Two strain gauges connected to a Wheatstone bridge measured the magnitude of the torsional moment The output from the Wheatstone bridge mounted directly on the distal end of the torsion shaft was displayed on a Peekle analyser (Peekle Universal Amplifier, type 591 DNH, Holland) The output from the analyser (magnitude of torsional moment) was further displayed on the vertical axis and the output from the potentiometer (angular deformation) on the horizontal axis of a paper recorder (Hewlett Packard, type 7015 A). As the angular velocity was constant during each experiment, the torque moment was determined as a function of the angular deformation of the specimen (Figure 4)

Calibration of the torsiometer

The linearity of the measurements obtained with the equipment was evaluated with a calibration torque wrench connected to the torsiometer exerting different known torques on the measurement

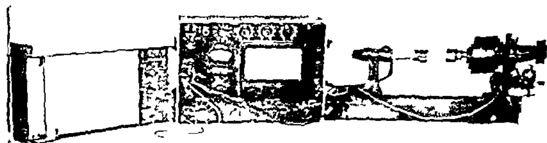


Figure 1 The torsional apparatus with the torsion device, Peekle micro-strain analyser and paper recorder

ence There was a linear relation between the magnitude of the torque applied and the output signal of the analyser (Figure 2) Comparable results were obtained with left- and right-handed rotation on the turning head. Figure 2 depicts the relation between the various forces applied with the calibration torque wrench (kpm) and the percentage deviation of the corresponding output signals obtained. The data indicate that the proportional error increases exponentially as the ... of the force on the test specimen is ... At maximal loading of the test equipment (0.4 kpm) the proportional precision of the test ... was 1 0–1.5 per cent In the animal experiments, the torque applied to the bones ranged from 0.15 to 0 20 kpm The measuring error of the torsiometer at this range of load was less than ... per cent.

Mechanical testing of the bones

Before the test procedure the fibula was sawn through at the tibio-fibular junction leaving a stump of bone of 1-2 mm. Each end of the specimen was embedded in a nut with epoxy resin (Stabilit Express, Henkell, Germay) which has a mean hardening time of 20 minutes The length of the shaft between the nuts was 8 5 centimeters in ... specimens The resin retained a constant volume during solidification. While the resin solidified the bones were laid against an L-shaped metal support, so that the nuts were held perpendicular to the specimen

Connection between the bone specimen and the torsional equipment was achieved by inserting the nuts into two tightly fitting holders (Bahco 30 mm ϕ) firmly connected to the torsiometer (Figure 3) No motion could be observed between the test specimen and the equipment

This rapid fixation procedure (30 minutes for a single specimen) made it possible to analyse the torque resistance of fresh bone without any storage procedure before testing Close up photographs were taken of all the fractured specimens for later analysis of the fracture line (Figure 3)

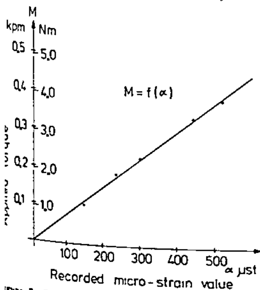
Biomechanical calculations

A typical load-deformation curve of a tibial bone is shown in Figure 4

Maximum torque moment (M_t) was determined from the maximum deflection of the curve (to the nearest 0 1 mm) and expressed in Nm

Maximum angle deformation (θ) was measured directly from the horizontal axis of the curve and expressed in degrees.

Energy absorbed until ultimate failure (W_t) *of the bone* was calculated from the area under the curve, which was measured with a planimeter (type HAFF 317) ($W_t = \int_0^{\theta} M_t \, d\theta$) The values were expressed in Nm (Burstein & Frankel 1971)



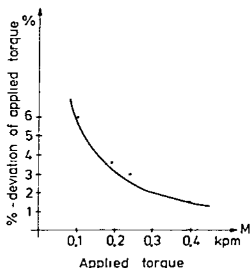


Figure 2 On the left linear relation between force applied and results obtained Ordinate known torque applied, Abscissa micro-strain value recorded

Figure 2 On the right the percentage deviation of the readings from the torque applied at various strengths

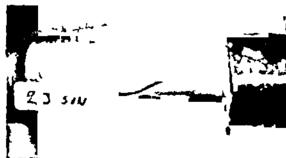


Figure 3 A typical spiral fracture after torsional loading of normal rabbit tibio-fibular bone The crack cuts through the tibio-fibular junction at 45 degrees to the longitudinal axis of the specimen

Torsional rigidity (G) of the specimen was measured from the slope of the linear portion of the curve and expressed in Nm/degree ($G = dM_t/d\theta_t$) (White et al 1974 Panjabi et al 1973)

The difference between results obtained for the right and left paired bones was expressed as

$$\left[\frac{(X)\ \text{right} - (X)\ \text{left}}{(X)\ \text{right} + (X)\ \text{left}/0.5}\right] 100 = \%\ \text{difference}$$

The data were processed with a computer and standard statistical methods were employed to test the significance of the results $P > 0.05$ was taken as non significant The possibility that one measured variable influenced any other was examined by correlation analysis and the coefficient of correlation (r) calculated The percentage error of the differences between the paired bones was calculated from duplicate determinations (standard error of the means, SEM) using the formula $SEM = \sqrt{d^2/2n}$, where d is the difference between duplicate measurements and n the number of pairs of bones measured

Measurement of bone dimensions

At sacrifice both tibio-fibular bones were radiographed on contact film. The entire length of the bone was measured directly from these radiographs.

After the torque test procedure a standardized transverse section was sawn from the tubular bone at the level of the tibio-fibular junction Contact microradiographs of these specimens were made on high resolution X ray film The area of cross section and medullary cavity was planimetered from tenfold enlargements of these radiographs. The values so obtained were reduced mathematically to the actual size of the bone The outer and inner diameters of the tube were determined with the same techniques.

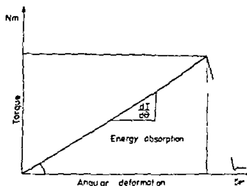


Figure 4 Load deformation curve where torque moment is determined as a function of angular deformation Energy absorption equals the area under the curve and torsional rigidity was determined from the slope of the linear portion of the curve

Chemical analysis

Each fresh tubular section was weighed and stored in airtight containers and deep-frozen for chemical analysis.

The contents of calcium phosphorus, hydroxyproline, hexosamines and total nitrogen were determined at the Department of Medical Chemistry, University of Turku with the techniques previously described by Penttinen (1972).

RESULTS

The fractures produced were remarkably uniform in type In all specimens there was a spiral fracture at 45 degrees to the longitudinal axis of the bone, with an additional spiral crack running up and down the bone beyond the actual limits of the fracture (Figure 3) The fracture appeared at the level of the tibio-fibular junction In paired bones the two fractures seemed to be identical in appearance The load-deformation curves, although very similar in shape varied greatly in termination point The mechanical properties of the bones in relation to the weights of the animals are presented in Table 1

Correlation between body weight bone dimensions and mechanical properties of bone

There was a highly significant correlation ($P < 0.001$) between body weight and the

Table 1 Torsiometric characteristics of rabbit tibio-fibular bones (with an angular velocity of 3 6 degrees/second)

Animal No	Body weight (g)	Maximum torque moment (Nm) Right	Left	Maximum angular deformation (degrees) Right	Left	Energy absorption at fracture (Nm) Right	Left	Torsional rigidity (Nm/degrees) Right	Left
1	(2400)	0 68	0 81	3 60	3 51	0 03	0 03	0 19	0 23
2	(2610)	1 07	0 96	5 18	4 43	0 06	0 04	0 19	0 21
3	(2660)	1 33	1 38	6 37	6 94	0 09	0 10	0 19	0 20
4	(2730)	1 07	1 01	6 15	5 18	0 07	0 05	0 16	0 19
5	(2750)	1 38	1 12	7 11	7 07	0 10	0 09	0 20	0 19
6	(3005)	1 38	1 45	7 38	7 07	0 11	0 09	0 20	0 21
7	(3050)	1 08	0 96	5 14	5 00	0 06	0 05	0 21	0 19
8	(3100)	1 12	1 10	6 10	5 84	0 07	0 07	0 17	0 18
9	(3200)	1 30	1 23	7 46	6 59	0 10	0 08	0 16	0 18
10	(3250)	1 37	1 36	4 48	4 79	0 06	0 07	0 33	0 28
11	(3530)	1 22	1 26	5 71	5 88	0 07	0 08	0 22	0 22
12	(3800)	1 40	1 34	5 36	5 36	0 08	0 07	0 26	0 25
13	(4050)	1 21	1 36	4 08	4 14	0 05	0 06	0 30	0 30
14	(4150)	1 84	1 86	7 16	6 50	0 14	0 12	0 28	0 31
15	(4850)	1 90	1 89	6 19	6 01	0 12	0 12	0 33	0 31
Mean (s.d.)		1 29 (0 30)	1 27 (0 31)	5 83 (1 20)	5 60 (1 13)	0 08 (0 03)	0 07 (0 03)	0 23 (0 06)	0 23 (0 05)

Table 2 Correlations of the body weight of the animals and bone dimensions with the biomechanical properties of rabbit tibio-fibulae Correlation coefficients and significance levels are presented and, if negative, marked –

	Maximum torque moment	Maximum angular deformation	Energy absorption at fracture	Torsional rigidity
Body weight	0 794 (+++)	0 092 (N S)	0 552 (++)	0 773 (+++)
Entire cross-sectional area	0 400 (+)	–0 240 (N S)	0 098 (N S)	0 647 (+++)
Area of cortical bone	0 351 (N S)	–0 320 (N S)	0 037 (N S)	0 679 (+++)
Bone length	*0 500 (++)*	*0 381 (+)*	*0 482 (++)*	*0 341 (N S)*
Outer diameter of tubular bone	0 185 (N S)	0 272 (N S)	0 043 (N S)	0 480 (++)
Inner diameter of tubular bone	0 327 (N S)	0 045 (N S)	0 171 (N S)	0 389 (+)

N S = not significant
(+) = $P < 0\ 05$
(++) = $P < 0\ 01$
(+++) = $P < 0\ 001$

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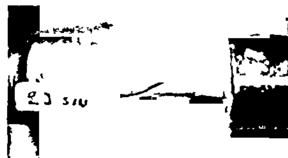


Figure 3 A typical spiral fracture after torsional loading of normal rabbit tibio fibular bone The crack cuts through the tibio-fibular junction at 45 degrees to the longitudinal axis of the specimen

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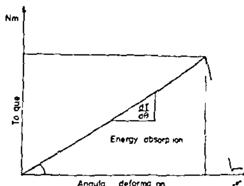


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'e 4 Chemical composition of rabbit tibio-fibulae Data of right and left paired bones expressed as mg/g dry weight of bone

e	Calcium (s.d)	Phosphorus (s d)	Hydroxyproline (s.d)	Hexosamines (s.d)	Nitrogen (s.d.)
ht	256 5 (15 9)	119 6 (4 5)	28 7 (1 1)	2.04 (0 28)	34 7 (1 5)
t	248 5 (22.3)	118 1 (3 1)	28 2 (1 2)	2.19 (0 39)	36 9 (5 5)
st for red bones	N S	N S	N S	N S	N S

Correlation analysis revealed no significant rrelations between the mechanical pro- rties and chemical composition of the mes.

ISCUSSION

one is a composite material exhibiting astic, viscoelastic and plastic properties edlin 1965, Burstein et al 1975) It can sist tensile forces as compared to com- ressive forces in a ratio of about 3 · 4 Currey 1970) Consequently the great majority of cortical bone fractures are caused y tensile forces, regardless of whether the orce responsible is tension, bending or orsion The ultimate tensile strength of bone s less than the ultimate shear strength Therefore in torsion, shear forces result in tensile and compressive forces acting at angles of 45 degrees to the plane of shear (Figure 5), and a spiral fracture occurs at 45 degrees to the axis of the bone

Bone can absorb noticeably more energy when force is applied at high velocity (Sammarco et al 1971, Panjabi et al 1973) Hence bone behaves as a tough material at slow strain rates and as a brittle material at high strain rates The microscopical appearance of the fracture line has been reported to be different in low- and high-velocity fractures (Piekarski 1970) Halving and doubling of low velocities, as in the present study, does not significantly change the maximum torque capacity (Stromberg & Dalen 1976b)

Paired bone specimens exhibited varying mechanical properties. According to many investigators, however, right-left differences in bones from different animals and human

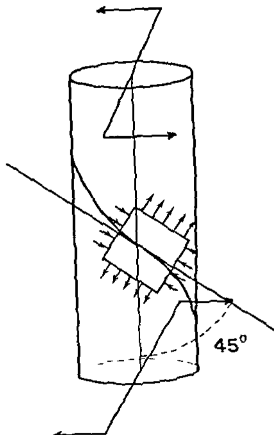


Figure 5 Shear forces arising from torsion, resulting in tensile and compressive forces at 45 degrees to the plane of shear A spiral fracture will occur at 45 degrees to the axis of the bone

cadavers have no statistical significance (Currey 1969, Puhl et al 1972, White et al 1974, Stromberg & Dalen 1976b) This was confirmed in the present study However, the *right-left variation in mechanical properties of* paired bones must be known in any biomechanical investigation in which the contralateral bones are to be used as controls Stromberg & Dalen (1976b) reported the variation for torque capacity in canine femora to be 3 1 per cent, compared with 6 3 per cent in this report The difference may be due to the different species used and to the almost ten-fold greater torsional moment used in their investigation

The results suggest great variation in the amount of energy absorbed until fracture This agrees with the observations reported by Bechtol (1959) in bending tests and Puhl et al (1972) in torsional testing The present results show that bone can sustain very little angular deformation without fracturing Accordingly, changes in angular deformation lead to considerable variation in the energy absorption capacity of bone

A high correlation was established between body weight and the dimensions of the tubular bone The biomechanical variables measured, with the exception of angular deformation, were highly dependent on body weight, which corroborates the observations made by Lindsay & Howes (1931) Thus in a series of experimental animals of different weights torsional properties of whole bone specimens should be corrected for the weights of the animals, in order to arrive at comparable results.

As was expected, these normal animals showed little variation in the chemical composition of the bone, and no significant differences were observed between paired bones. In normal bone specimens the dimensions of the bone are more important for the maintenance of torsional strength than are the changes in the chemical content of the bone With the known error of the test equipment and the biological variations of paired bones, this torsiometric assessment of bone strength is a suitable method for analysis of biomechanical bone characteristics

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REFERENCES

Ascenzi, A & Bonucci E (1967) The tensile properties of single osteons. *Anat Rec* 158, 375–385

Ascenzi A & Bonucci E (1968) The compressive properties of single osteons *Anat Rec* 161, 377–390

Bechtol C O (1959) Bone as a structure *Metals and engineering in bone and joint surgery* ed. Bechtol C O, Ferguson A B & Laing P G Williams & Wilkins Baltimore

Brooks, D B Burstein P H D & Frankel V H (1970) The biomechanics of torsional fractures *J Bone Jt Surg* 52-A 507–514

Burstein, A H & Frankel V H (1968) The viscoelastic properties of some biological materials *Ann N Y Acad Sci* 146, 158–165

Burstein A H & Frankel V H (1971) A standard test for laboratory animal bone *J Biomech* 4, 155–158

Burstein A H, Zika J M Heiple K G & Klein, L (1975) Contribution of collagen and mineral to the elastic-plastic properties of bone *J Bone Jt Surg 57-A, 956–961*

Currey, J D (1969) The mechanical consequences of variation in the mineral content of bone *J Biomech* 2, 1–11

Currey J D (1970) The mechanical properties of bone *Clin Orthop* 73, 210–231

Dempster, W T & Coleman R F (1961) Tensile strength of bone along and across the grain. *J appl Physiol* 16, 355–360

Lindsay, M K & Howes, E. L. (1931) The breaking strength of healing fractures. *J Bone Jt Surg* 13, 491–501

McElhaney, J H (1966) Dynamic response of bone and muscle tissue *J appl Physiol.* 21, 1231–1236

Panjabi M M White III A A & Southwick

" O (1973) Mechanical properties of bone as unction of rate of deformation *J Bone Jt rg* 55 A, 322–330
nen R. (1972) Biochemical studies on cture healing in the rat *Acta chir scand*, ppl 432
ski, K (1970) Fracture of bone *J appl ysiol* 41, 215–223
J J, Pietrowski, G & Enneking, W F 972) Biomechanical properties of paired nine fibulas *J Biomech* 5, 391–397
narco G J, Burstein A H, Davis, W L & ankel V H (1971) The biomechanics of rsional fractures the effect of loading on timate properties. *J Biomech* 4, 113–117
a, E. D (1965) A rheologic model for cortical one A study of the physical properties of man femoral samples. *Acta orthop scand*, uppl. 83
n, E. D & Hirsch, C. (1966) Factors affecting e determination of the physical properties of femoral cortical bone *Acta orthop scand* 37, 29–48
Stromberg, L & Dalen, N (1976a) The influence of freezing on the maximum torque capacity of long bones An experimental study on dogs *Acta orthop Scand* 47, 254–256
Stromberg, L & Dalen, N (1976b) Experimental measurement of maximum torque of long bones. *Acta orthop scand* 47, 257–263
Vincentelli, R & Evans, F G (1971) Relations among mechanical properties, collagen fibres and calcification in adult human cortical bone *J Biomech* 4, 193–201
Vose, G P (1962) The relation of microscopic mineralization to intrinsic bone strength *Anat Rec* 144, 31–36
White III, A A, Panjabi, M M & Hardy R J (1974) Analysis of mechanical symmetry in rabbit long bones *Acta orthop scand* 45, 328–336

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STUDIES ON MECHANICAL STRENGTH OF BONE

II *Torsional Strength of Cortical Bone after Rigid Plate Fixation with and without Compression*

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Biomechanical properties of intact rabbit tibio-fibulae were investigated with torsional loading 1 day to 36 weeks after fixation using 4-hole stainless steel ASIF/DCP plates with and without compression

During the first 12 weeks energy absorption and torque moment increased slightly as a result of subperiosteal new bone formation following application of the plates There was a concomitant increase in the yield properties of the bone reflecting progressive porotic transformation Thereafter up to 36 weeks postoperatively the values for energy absorption torque moment and angular deformation gradually declined in both groups of bones. The differences between normal control bones and plated bones at 36 weeks were 70 1 53 0 and 26 3 per cent respectively The decay of torsional strength was the same whether or not compression was used in the plate fixation

The results suggest that even in normal bone rigid plates induce a considerable loss of strength due to the cancellous transformation they are known to cause in cortical bone

Key words bone bone plates fracture fixation experimental measurement of bone strength

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Rigid plate fixation of fractured bones initially provides conditions conducive to primary bone healing but protection of the bone from normal loading stress may induce atrophic changes and a decrease in the mechanical strength of the bone during the later stages of repair Refractures have been reported after removal of the plates (Richon et al 1967, Dietschi & Zenker 1973 Solheim 1974)

Both adverse effects on bone tissue as a structure (Schenk & Willenegger 1967, Uhthoff & Dubuc 1971 Gordes et al. 1975a, 1976) and reduction of the bone mineral mass (Gordes et al 1975b Stromberg & D.. 1976) have been reported in cortical .. after immobilization with a rigid plate .. magnitude of the bone changes seems .. depend on the stiffness of the plate .. structural alterations have been less .. after the use of plates with mechanical properties resembling those of bone (Akeson .. al 1975, Tonino et al 1976 Woo et al 197.. The axial compression applied to the f.. and conveyed to the underlying bone does .. appear to alter the mechanism of .. repair (Lettin 1965 Perren et al 1969), .. scant attention has been paid to the effect

ession on the mechanical properties of al bone

e object of this study was to measure hanges in torsional strength at different intervals after application of rigid plates ormal rabbit tibio-fibular bones, and to ss the effect of additional axial plate compsion on the changes observed

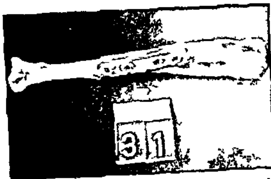


Figure 1A Rabbit tibio-fibular bone 36 weeks after application of a rigid steel plate Note the formation of new subperiosteal bone round the plate

TERIAL AND METHODS

ratire procedure

tes were appl ed to the tibio-fibulae of 40 adult b ts weighing from 2400 to 3850 g The bone s exposed through a straight lateral incision d a commercial stainless steel four hole dynamic mpression plate (ASIF/DCP) was attached mly to the anterolateral face of the tibia The o-fibular junction served as a landmark for the act pos tioning of the midpoint of the plate On e right tibia, compression was applied between e most proximal and the most distal screw and e two middle screws were tightened in a neutral ish on The entire tubular segment between the wo outermost screws was thus subjected to com ression. On the left tibia, a similar four hole plate as attached to the bone without compression

Postoperatively the animals were housed in separate cages in which they could move freely Seven animals were excluded from the analysis because of infection (1) or subsequent fracture under the plate (6) In one animal a fracture occurred in the right leg in one animal in the left and in four animals in both legs.



Figure 1B A typical spiral crack passing through a screw hole at the tibio-fibular junction (arrow) after torsional loading of the bone specimen 36 weeks postoperatively Note the porotic cavitation of the cortical bone under the plate

Testing of the mechanical properties

The animals were killed 1 and 3 days, and 1 3 6, 12, 18 24 and 36 weeks after the operation The tibio-fibular bones were exarticulated and freed from any soft tissue but the periosteum and any callus tissue were preserved intact.

Prior to the test procedure the bones were radiographed before and after removal of the plates. Examination of the radiographs excluded three more animals from the analysis because of faulty positioning of the plate or fractures at the level of the screw holes. In order to eliminate the stabilizing effect of the fibula, this was severed distally at the tibio-fibular junction leaving a proximal remnant of 1 2 mm. The specimens were kept in physiological saline at room temperature before the test

As previously described (Paavolainen 1978) the ends of the bones were embedded in nuts with epoxy resin leaving a constant length (8 5 cm) of bone for testing The specimen was then fitted into the sockets of the torsiometer and subjected to external rotation at a constant deformation speed of 3 6 degrees/second

Calculations

From the load-deformation curve obtained which represents the torque moment as a function of the angular deformation of each specimen the following biomechanical properties were measured

As reported earlier (Paavolainen 1978) the mechanical properties of the rabbit tibio-fibular bone apart from angular deformation are

critically dependent on the body weight of the animal Hence the data obtained for each bone specimen were corrected for the weight of the animal. Using linear regression curves for body weight in relation to torque moment energy absorption and torsional rigidity in the control series, the biasing effect of body weight was reduced by multiplying the test values obtained by a constant which standardized them for the mean body weight (3275 g) of the control group

Mechanical properties of 57 specimens were analysed successfully three specimens had to be discarded because of technical failure The 57 specimens were divided into five groups according to when the animals were killed 1-3 days (4+4 specimens) 1-3 weeks (9+9 specimens) 6-12 weeks (7+8 specimens) 18-24 weeks (5+5 specimens) and 36 weeks postoperatively (3+3 specimens) The means and their standard deviations were calculated for each of these Statistical analysis of the influence of compression was made in paired bones and of the influence of time after plating in the different groups The statistical significance of the differences between the paired bones was assessed with a paired t test Between the various groups statistical analysis for two means was made $P > 0.05$ was taken to be non significant

Sources of error

The experimental error for biomechanical differences between paired bones of the same animal, expressed as SEM values for the percentage deviations of the paired variables measured from the mean value was as follows torque moment at fracture 6.3 per cent deformation at fracture 5.7 per cent energy absorbed at fracture 10.0 per cent, torsional rigidity 7.1 per cent There was no statistically significant right-to-left dominance between the pairs of bones (Paavolainen 1978)

RESULTS

The biomechanical properties of the bones plated with and without compression in the various age groups are shown in Figure 2 During the first three postoperative days, the torque moment of both the compression and neutrally plated bones fell by almost one standard deviation compared with the values for normal bones reflecting the weakening effect of the screw holes in the tubular bone At 6-12 weeks postoperatively the torque moment had increased almost significantly ($P<0.05$) in the plated bones whether the plates were applied with or without compression Thereafter however the torque moment declined continuously up to the 36th week postoperatively In both types of plating the differences between the initial postoperative values and those obtained at 36 weeks were statistically significant ($P<0.01$)

Energy absorption i e the magnitude of the work needed to deform the bone up to the point of failure, increased steadily for 6-12 weeks postoperatively At this stage the values approached the values of energy absorption measured in normal bones Thereafter however the values of energy absorption in both groups of bones gradually declined The difference between the initial postoperative values and those at 36 weeks was highly significant ($P<0.001$) whether or not compression had been used at plating

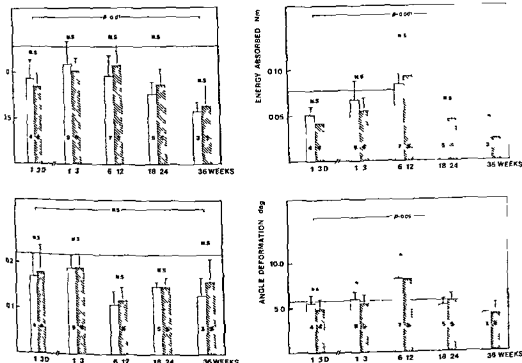
The changes in angular deformation were closely related to the changes in energy absorption The values for deformation seemed to reach a peak at 6-12 weeks postoperatively Thereafter they declined slightly The differences between the initial postoperative values and the values at 36 weeks postoperatively were almost statistically significant ($P<0.05$)

Only slight changes were observed in the values for the torsional rigidity of the bone. At 6-12 weeks postoperatively the increase in both energy absorption and angular deformation led to diminishing values of torsional rigidity This means that the slope of the load-deformation curve decreased although at the same time the maximum torque moment increased both of which factors led to increased values for energy absorption. At 36 weeks, the values for torsional rigidity seemed to approach the initial postoperative values. The differences between the values immediately after the operation and at 36 weel ... tistically ... nificant

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gure 2A D Biomechanical properties of intact rabbit tibio-fibular bones after exposure to rigid plates ith (white columns) and without (shaded columns) compression Vertical bars represent one standard viation. The figures in the columns denote numbers of specimens Statistical significance between mes pl … stope … ean v…

ISCUSSION

pplication of rigid steel plates to normal abbit tibio-fibular bones leads to progressive hanges in the affected bone The alterations re characterized by cancellous transformation of the cortex accompanied by increases n the diameters of the tubular bone and nedullary cavity (Paavolainen et al. 1978) The cancellous transformation of the bone is f the same magnitude after compression and fter neutral plate fixation (Slatis et al 1978) Morphologically, the porotic cavitation of the cortex closely resembles the changes observed during primary fracture healing (Schenk & Willenegger 1967, Olerud & Danckwardt-Lillestrom 1968 Uhthoff & Dubuc 1971 Gordes et al 1975a)

The present study reveals that plating causes considerable changes in the biomechanical properties of rabbit tibio-fibular bones For a few days postoperatively the screw-holes in the tubular bone caused a reduction in torque moment and energy absorption values (cf Burstein et al 1972) After this, the alterations seemed to occur in two phases In the first phase, 1 to 12 weeks after application of the rigid plate both the torque moment and the energy absorption values increased to almost normal values reflecting increasing strength of the bone as a structure Simultaneously, however there was an increase in angular deformation and a … ng … ne … ed

bone was obviously due to formation of new subperiosteal bone round the tubular bone (Paavolainen et al 1978)

The concomitant increase in the yielding properties of bone reflects the increasing cavitation of the cortex as a result of cancellous transformation (Slatis et al 1978)

In the second phase 18 to 36 weeks postoperatively, energy absorption and torque moment values decreased considerably Meanwhile the angular deformation decreased but torsional rigidity increased slightly This indicates that in the late stages of adaptation to the plate the bone as a structure loses both strength and flexibility The alterations during the second phase seem to coincide with progressive porotic cavitation of the cortex, which at 36 weeks amounts to over 40 per cent of the cortical bone (Slatis et al 1978) There were no significant differences between plate fixation with and without compression regarding the decline of biomechanical properties of the underlying bone Hence it seems that the changes observed are due to the rigidity of the plates and not to the compression *per se*

Stromberg & Dalen (1976) plated intact canine femora with commercially available rigid steel plates and compared the test specimens with control bones perforated with the same number of screw holes Seven months later they found a reduction of 18 3 per cent in torsional capacity and of 22.2 per cent in angular deformation Our results showed reductions of 53 0 per cent in torque moment and 26 3 per cent in angular deformation of the test specimens when compared at 36 weeks postoperatively with normal intact rabbit tibio-fibulae The data obtained indicate considerable loss of strength even in normal bones subjected to plating

REFERENCES

Akeson W H Woo S I Y Coutts, R D Matthews, J V Consalves, M & Amiel D (1975) *Quantitative histological evaluation of early fracture healing of cortical bones im*mobilized by stainless steel and composite plates. *Calcif Tiss Res* 19, 27-37

Burstein A H Currey J Frankel, V H Heple, K G Lunseth P & Vessely J G (1972) Bone strength The effect of screw-holes *J Bone Jt Surg* 54 A 1143-1156

Dietschi C. & Zenker H (1973) Refrakturen und neue Frakturen der Tibia nach AO-Platten- und Schrauben-Osteosynthesen. *Arch. orthop Unfall Chir* 76, 54-64

Gordes W., Kossyk W & Hollander H. (19[illegible]) Histologische und histomorphometrische Veranderungen bei Plattenosteosynthesen nach Osteotomien an der Tibia des Kaninchens *Arch orthop Unfall Chir* 82, 123 133

Gordes, W Kossyk W & Bodefeld, P (19[illegible]) Versuche zur Kalksalzdictenbestimmung an der osteotomierten und stabilisierten Tibia des Kaninchens. *Arch orthop Unfall Chir* 81 125-147

Gordes W (1976) Messungen zur Bestimmung der Spongiosierung unter Einfluss der Plattenosteosynthese *Z Orthop* 114 729 732

Lettin, A W F (1965) The effects of axial compression on the healing of experimental fractures of rabbit tibia *Proc roy Soc Med* 58, 882-886

Olerud S & Danckwardt Lillestrom, G (19[illegible]) Fracture healing in compression osteosynthesis in the dog *J Bone Jt Surg* 50-B 844-851

Paavolainen P Karaharju E & Slatis, P (19[illegible]) Radiographic changes in tubular bone after rigid plate fixation. *Acta radiol (Stockh.)* 19 119-126

[illegible] he mechanical [illegible] strength of [illegible] Acta orthop *scand* 49, 497-503

Perren S M Huggler A Russenberger M Allgower M Mathys, R., Schenk R Willenegger H & Muller M E. (1969) The reaction of cortical bone to compression. *Acta orthop scand* Suppl 125

Richon, A Livio, J J & Saegesser F (1967) Les refractures après osteosynthèse par plaque à compression *Helv chir Acta* 43 49 64

Schenk, R. & Willenegger H (19[illegible]) Morphological findings in primary fracture healing *Symp Biol Hung* 7, 75 86

Slatis, P., Karaharju, E., Holmstrom, T., Ahonen J & Paavolainen P (1978) Structural changes in intact tubular bone after application of rigid plates with and without compression. *J Bone Jt Surg* 60-A 516-522.

Solheim K. (1974) Tibial fractures treated according to the AO method *Injury* [illegible] 213 220

Stromberg L. & Dalen N (1976) Influence of

rigid plate for internal fixation on the maximum torque capacity of long bones *Acta chir scand* **142**, 115–122
Tonino A J, Davidson, C L, Klopper, P J & Linclau, L A (1976) Protection from stress in bone and its effects *J Bone Jt Surg* **58**-B, 107–113
Uhthoff, H K & Dubuc, F L (1971) Bone structure changes in the dog under rigid internal fixation *Clin Orthop* **81**, 165–170
Woo, S L-Y, Akeson, W H, Coutts, R D, Rutherford, L, Doty, D, Jemmot, G F & Amiel, D (1976) A comparison of cortical bone atrophy secondary to fixation with plates with large differences in bending stiffness *J Bone Jt Surg* **58**-A, 190–195

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REFERENCES

Akeson W H Woo S L-Y Coutts, R D Matthews J V Consalves, M & Amiel D (1975) Quantitative histological evaluation of early fracture healing of cortical bones immobilized by stainless steel and compos[illegible] plates. *Calcif Tiss Res* 19, 27–37

Burstein A H Currey J Frankel V H, Heipe, [illegible] K. G Lunseth P & Vessely J G (19[illegible]) Bone strength The effect of screw-holes. *J Bone Jt Surg* 54 A 1143–1156

Dietschi C. & Zenker H (1973) Refrakturen [illegible] neue Frakturen der Tibia nach AO-Platten- und Schrauben-Osteosynthesen. *Arch orthop Unfall Chir* 76, 54–64

Gordes W Kossyk W & Hollander H (19[illegible]) Histologische und histomorphometrische Veranderungen bei Plattenosteosynthesen nach Osteotomien an der Tibia des Kaninchens *Arch orthop Unfall Chir* 82, 123–133

Gordes W Kossyk W & Bodefeld P (19[illegible]) Versuche zur Kalksalzdichtenbestimmung an der osteotomierten und stabilisierten Tibia des Kaninchens. *Arch orthop Unfall Chir* 81 125–147

Gordes W (1976) Messungen zur Bestimmung der Spongiosierung unter Einfluss der Platten-osteosynthese *Z Orthop* 114, 729 732

Lettin A W F (1965) The effects of axial compression on the healing of experimental fractures of rabbit tibia *Proc roy Soc Med* 58, 882–886

Olerud S & Danckwardt Lilliestrom G (19[illegible]) Fracture healing in compression osteosynthesis in the dog *J Bone Jt Surg* 50-B 844–851

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Paavolainen P (1978) Studies on the mechanical strength of bone I Torsional strength of normal rabbit tibio-fibular bone *Acta orthop scand* 49, 497–505

Perren S M Huggler A Russenberger M Allgower M Mathys, R Schenk R Willenegger H & Muller M E. (1969) The reaction of cortical bone to compression *Acta orthop scand* Suppl 125

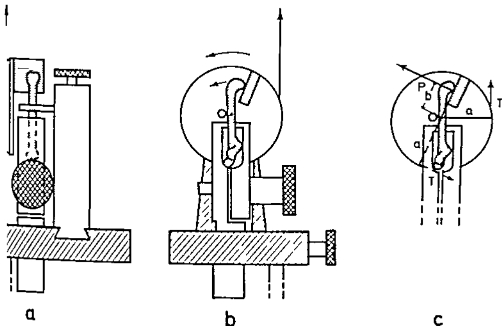
Richon A Livio J J & Saegesser F (196[illegible]) Les refractures après osteosynthèse par plaque [illegible] compression *Helv chir Acta* 43, 49 64

Schenk R & Willenegger H (1[illegible]) Morphological findings in primary fracture healing *Symp Biol Hung* 7, 75–86

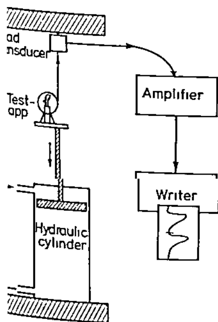
Slatis P Karaharju E Holmstrom, T. [illegible] J & Paavolainen, P (1978) Structural changes in intact tubular bone after application of rigid plates with and without compression *J Bone Jt Surg* 60-A 516–522.

Solheim K (1974) Tibial fractures treated according to the AO method *[illegible]* 4, 213–220

Stromberg L. & Dalen N (1976) Influence of [illegible]



The bending apparatus — frontal (a) and lateral (b) view Figure 1c shows that the moment d (T×a) equals the moment needed to bend the distal part ventrally relative to the proximal (b) (Rø et al 1976)



2 Equipment for measuring mechanical ies of the rat femur

The force T is applied by a hydraulic tensile testing machine type 7-1/1 (AB Lorentzen & Wettres Maskinaffär, Stockholm, Sweden) (Figure 2) The tension in the wire is measured with a load transducer (HBM Kraftaufnehmer Type U1, load range 0–10 kp, Hottinger Baldwin Messtechnik, Darmstadt, W Germany) which is connected via an amplifier (HBM Messverstarker KWS/T-5) to a chart recorder (Riken Denshi Co Ltd, Model SP-J5B, Tokyo, Japan) The force is applied with a constant deformation rate, 0 04 radians per second (2 5 degrees per second)

A typical bending stress-strain curve of the intact femur diaphysis is shown in Figure 3 The curve gives information about the maximum stress, the stiffness of the bone in the linear elastic part of the curve (tg α) and the angle of deformation necessary to produce fracture (fracture angle) The area below the curve expresses the energy which the bone can absorb before fracture

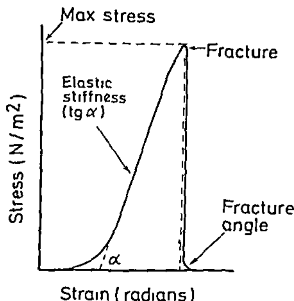


Figure 3 Stress strain curve for bending of the rat femur diaphysis

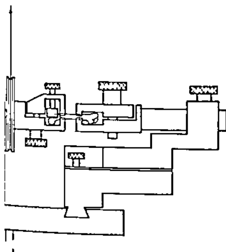
(2) Epiphyseal plate/metaphysis bending tests

The bending moment necessary to produce epiphysiolysis and metaphyseal fracture can also be tested The bone is placed as shown in Figure 4a with the disc centre and the fulcrum pin just proximal to the epiphyseal plate

With this arrangement the cam on the disc will first give epiphysiolysis followed by dislocation of the epiphysis By continual rotation of the disc the distal part of the *metaphysis will fracture* The resulting moment-deformation curve (Figure 4b) has two peak values, the first one represents epiphysiolysis and the second one represents metaphyseal fracture of the bone As the epiphyseal discs of the long bones in rats do not close (Farris & Griffith 1949) this test method is not restricted to young rats

Metaphyseal fracture
Epiphysiolysis
Moment (Nm)
Strain (radians)
a
b

Figure 4 Testing of the epiphyseal plate and the metaphysis in bending (a) Rotation of the disc will first give epiphysiolysis and then metaphyseal fracture This is recorded as two peak values in the moment deformation curve (b)



re 5 *The arrangement for torsional testing force is applied via a rotating disc as in the ing apparatus*

Diaphyseal torsional tests

he torsional testing system is illustrated Figure 5 The torsional moment is, as in bending apparatus, applied via a rotating : The distal end of the femur is attached the disc via a special clamp The clamp ch fixes the proximal end of the femur can moved horizontally and adjusted to erent angles when testing fractures united ngulated positions The clamps are con- cted to envelop the ends of the bone ure 5) Therefore only part of the rotating e is transferred to the bone via the claws he clamps, the rest being transferred by body of the clamps This arrangement ces the stress concentration and the nce for fracture at the claws

he tension of the wire and thereby the led moment is continually measured as ribed in the bending tests The stress- in curve is also principally the same ure 3). The bones can be tested by both ard and outward rotation of the distal t relative to the proximal part

RESS CALCULATIONS

: stress in the test bone (force/cross- ional area) depends not only on the applied moment, but also on the shape and the area of the cross section of the bone Because of variation in the size and shape of the femurs, not only from one femur to another, but also along the diaphysis in the same bone, the stress calculations can only be approximate

In earlier investigations these problems have been simplified by calculating the cross-sectional area of the femur as a hollow ellipse (Bell et al 1941). The formula for the maximal bending stress of an elastic isotropic, homogeneous beam with a hollow elliptical cross section, derived from Roark & Young (1975) is

$$\text{Max bending stress} \quad \sigma_m = \frac{M\times b}{I} = \frac{4\times M\times b}{\pi(ab^3-(a-t)(b-t)^3)} \quad (1)$$

where M is the maximal bending moment, a and b are the major and minor external radii of the hollow ellipse t is the thickness of the hollow ellipse and I is the area moment of inertia for an ellipse

The maximal torsional stress for a hollow ellipse is

$$\tau_m = \frac{T\times b}{I_p} = \frac{4\times T\times b}{\pi(ab^3+a^3b-(a-t)(b-t)^3-(a-t)^3(b-t))} \quad (2)$$

where T is the maximal torsional moment and I_p is the polar moment of inertia for a hollow ellipse

Obviously the cross section of the femur of the rat deviates from a hollow ellipse To estimate the magnitude of this simplification, six rats (Wistar SPF, with mean weight 278 ± 12 g) were investigated A slice from the middle of the right femur was photographed through a microscope and magnified (25×) (Figure 6) The cross-sectional area was measured by a planimeter The area and polar moment of inertia were calculated by graphical integration The area moment of inertia is $\sum x^2 dA$, where dA is the

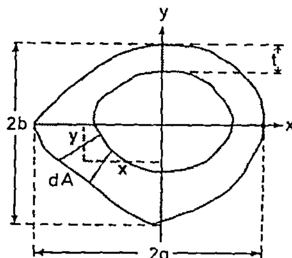


Figure 6 Cross section of the middle part of the rat femur diaphysis 2a and 2b represent the major and minor diameters t the ventral thickness x and y the distance of the elemental area dA, from the diameters

elemental area (Figure 6) The polar moment of inertia is $\sum(x^2+y^2)dA$

The femur dimensions were measured using a sliding callipers (accuracy of ± 0 01 mm) The thickness of the femoral cortex (t in the equations (1) and (2)) was measured ventrally in the middle of the femur (Figure 6) The major diameter (2a in the equations) and the minor diameter (2b in the equations) were also measured in the middle of the femur

The calculated values for the area and polar moment of inertia firstly regarding the femur as a hollow ellipse and secondly by direct measurements of the cross sectional area using planimetry, are given in Table 1

The mean calculated area moment of inert[ia] is 11 per cent higher than the measur[ed] value The calculated polar moment of iner[tia] is only 2 per cent higher than the measur[ed] value These differences will of course gi[ve] the corresponding differences in the maxim[al] stress values (see equations (1) and (2)).

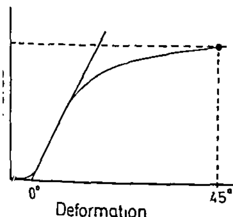
To get an impression of the absol[ute] differences in the maximal stress with th[e] measured and the "elliptical" moments [of] inertia, the maximal moment must be know[n]. Therefore, fresh femurs of two groups of s[...] rats were tested one group in bending an[d] the other in torsion These rats we[re] equivalent to the rats used for moment [of] inertia measurements. The mean maxim[al] bending and torsional moments were found t[o] be 0 44 Nm and 0 20 Nm respectively Th[e] measured and "elliptical" maximal bend[ing] and torsional stresses calculated from th[e] equations (1) and (2) are shown in Table 1

TESTING OF THE APPARATUS

To estimate the accuracy of the appara[tus] polished steel rods (diameter 1 70 mm) we[re] tested, ten for bending and eight for torsion[al] strength At the same rate of testing as th[e] rat femurs the steel rods did not fracture bu[t] exhibited plastic deformation Therefore th[e] force value at 0 79 radians (=45 degrees) deflection was chosen since this wa[s] representative of the force level seen in th[e] bone experiments (Figure 7)

Table 1 Calculated and measured values for the area moment of inertia bending stress and the po[lar] moment of inertia/torsional stress in the rat femur

	The area moment of inertia (± standard deviation)	Max bending stress	The polar moment of inertia (± standard deviation)	Max torsional stress
Calculated values	4 07 ± 0 60 mm^4	1 62 10^8 N/m^2	10 63 ± 0 87 mm^4	2 91 10^7 N[...]
Measured values	3 63 ± 0 52 mm^4	1 82 10^8 N/m^2	10 45 ± 1 14 mm^4	2 96 10^7 N[...]



gure 7 The force deformation curve for the steel ds in bending (principally the same for torsion) he force value at 45 degrees deflection is marked he deflection is calculated to start where the ngent to the elastic part of the curve crosses the oscissa

The formulas for maximal stress for a solid rcular rod (Roark & Young 1975) are

laximal bending stress $\sigma_m = \frac{M \times r}{I} = \frac{4M}{\pi r^3}$ (3)

here r is the radius of the circular rod The mean bending stress at 45 degrees was 73 x 10⁶N/m² (Standard deviation (s d) 0 8 er cent)

laximal torsional stress $\tau_m = \frac{T \times r}{I_p} = \frac{2T}{\pi r^3}$ (4)

he mean torsional stress at 45 degrees was 04 x 10⁶N/m² (s.d. 1 3 per cent)

DISCUSSION

he test system which is described is a mple and accurate method for testing the echanical properties of both intact rat murs and fractured femurs in different hases of healing

The objections to this test system can be ivided into mechanical and biological ictors.

Beside the limitations of the load ansducer, amplifier, chart recorder and tensile testing machine, some mechanical inaccuracies are known The weight of the cam on the disc gives tension in the wire, but this is below the sensitivity of the transducer/chart recorder (i e less than 0 05 N) Friction both in the ball-bearings and between the bone and the cam on the disc is probably greater, but difficult to estimate The overall accuracy of the apparatus tested by the steel rods gave, however, a standard deviation of about 1 per cent This indicates rather accurate measurements, especially since this deviation may partly be caused by variation in the steel rods

The biological part, i e the test bones, is probably the main source of errors in the test system Angulations in the united fractures will give an unwanted bending moment when tested in torsion, which may result in a reduced measured moment The magnitude of this error depends on the extent of the angulation Approximations have to be made in the calculation of the stress from the measured moments and dimensions. Firstly, in the calculations the stress-strain curve is assumed to be linear up to the fracture Weir et al (1949) found that air-dried rat femur remained elastic only up to three-quarters of the maximal bending stress Also in the present study the bones displayed plasticity near fracture (Figure 3) This plasticity may make whole bones considerably stronger (Currey 1969 and Burstein et al 1972) Secondly, bone is not a homogeneous material, but it is penetrated by stress concentrators such as blood vessels, canaliculi and osteocytic lacunae In addition, the muscle insertions make the surface uneven Thirdly, the calculations ignore the effect of shear stress, but this error was estimated to be very small (about 0 25 per cent) in another cantilever system (Smith & Walmsley 1959) The fourth assumption is that the cross section of the femur diaphysis is simplified to be a hollow ellipse In our investigation this simplification is estimated to give a difference of 11 per cent for the area moment of inertia and 2 per cent for the polar moment of inertia This is in accordance with

Mather (1967) who found that the mean value for the elliptical calculated area moment of inertia of human femurs was 14 5 per cent higher than the measured value

These inaccuracies in stress calculations are very difficult to avoid but some of them are systematic and will therefore be less important when different groups of bones are compared

The method of testing the maximal bending moment of the epiphyseal plate and the metaphysis makes it possible to test the growing cartilage and newly produced bone Both should be important for example when investigating the influence of drugs and hormones on the bone growth.

The test apparatus described is constructed as a modular system The main parts of it are used both in the testing of bending and torsional properties It can also be used for tensile strength measurements but bones are normally very seldom subjected to pure tensile stress

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REFERENCES

Bel [illegible]

Burstein A H Currey J D Frankel V H Reilly D T (1972) The ultimate properties of bone tissue The effects of yielding J Biomech 5, 35 44

Currey J D (1969) The mechanical consequences of variation in the mineral content of bone J Biomech 2, 1–11

Mather B S (1967) A method of studying the mechanical properties of long bones J Physiol 7, 226—230

Farris E J & Griffith J Q (1949) The ra[illegible] 2nd ed pp 24[illegible]

Form[illegible] stress and strain 5th ed McGraw Hill Book Co New York 624 pp

Rø J Sudmann E & Marton P F (19 6) Effect of indomethacin on fracture healing in rats Acta orthop scand 47, 588–599

Smith J W & Walmsley R (1959) Factors affecting the elasticity of bone J Anat (Lond) 93, 503 523

Weir J B de V Bell G H & Chambers J W (1949) The strength and elasticity of bone in rats on a rachitogenic diet J Bone Jt Surg 31 B 444–451

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JOINT CHANGES AFTER OVERUSE AND PEAK OVERLOADING OF RABBIT KNEES *IN VIVO*

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The effect of overuse and overuse combined with axial peak overloading on the knee joints of living rabbits has been investigated A specially constructed apparatus was used for this purpose Physical and biochemical changes are reported and include

1 Early and progressive damage to the articular cartilage surface shown by the scanning electron microscope
2 The presence of an increased amount of prostaglandin E in the synovial fluid
3 A reduction of cyclic 3 –5 adenosine monophosphate in the subchondral bone
4 Late changes which were consistent with osteoarthritis

These changes were found only in the joints subjected to simultaneous overuse and peak overloading

The results suggest that

1 Cartilage damage and chemical changes in the subchondral bone are simultaneous and are both responsible for eventual degenerative changes
2 Frictional overuse alone does not seem to be responsible for the production of osteoarthritis.

Key words Cyclic 3 –5 adenosine monophosphate overuse peak overloading prostaglandin E scanning electron microscope

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Weight bearing joints are subjected to two kinds of stress. One is a shear stress produced by reciprocal friction of the articulating surfaces and the other is produced by axial longitudinal loading Clinical conditions in which either of these stresses is abnormally increased may induce degenerative changes.

Accordingly, experiments designed to reproduce such changes have involved either modifications of the articular surfaces by chemical or mechanical means (Bennet & Bauer 1937, Trias 1961 Crellin & Southwick 1964 Murray 1964 Hulth et al. 1970) or by increasing the axial longitudinal loading (Simon et al. 1972, Radin et al 1973)

However, *in vivo,* both stresses are simultaneous and cannot be separated. It was thought important therefore to explore this simultaneous action in the living animal under controlled conditions which allow the separation of these effects.

The present study reports the physical and biochemical changes found in knees of living rabbits after these joints were subjected simultaneously to frictional and loading stress by means of a specially constructed apparatus. One joint was subjected to both stresses. The contralateral one, serving as a control was subjected to frictional stress only

EXPERIMENTAL PROCEDURE

White New Zealand adult female rabbits weighing 3–4 kg were used Skeletal maturity as evidenced by the closure of the lower epiphysis of the femur and the upper epiphysis of the tibia was ascertained roentgenographically Each rabbit was anaesthetized by open mask Fluothane (ICI) and maintained by the addition of 10 mg/kg of Nembutal (Abbott Laboratories) Under sterile conditions, incisions were made both on the lateral and medial aspects of the thigh and the leg 3 cm away from the knee joint line Through these incisions two parallel round stainless steel pins were introduced, one into each bone with the aid of a low speed dental handpiece drill The pin used for the femur was 2.4 mm in diameter and that for the tibia was 2.9 mm (Stainless steel Zimmer, USA) The skin was then closed by silk sutures. A small pad with Betadine was applied around the protruding pins

The animal was then tied to a specially constructed apparatus This consisted of a platform (on which the animal could rest with its legs hanging down) and an electric motor (60 watt) which moved a wheel. The upper two pins, one for each femur, were secured to the body of the apparatus The legs and the feet were connected to the driving wheel by means of a flexible rod Because of the eccentric attachment of the rod, the rotation of the wheel produced alternative flexion and extension of the knees (Figure 1).

Each revolution of the wheel moved the knee joints from flexion of 80° to full extension A forked device which was connected to the driving wheel produced direct impulsive peak overloads to the pin of one of the tibiae This load was adjusted by a spring to a maximum of 35 g Therefore, each revolution of the driving whe caused

(a) movement of the two knees from 8 flexion to full extension and

(b) at the point of full extension of both kne peak overloading was applied to the left k

Because of the rigid fixation of the bone to th apparatus the peak loads exerted on the kn joints were direct and bone conduct Furthermore, the constant distance of the pi from the knee joint enabled identical experime conditions regardless of the size of the anim legs The forces applied to the joints, either in t number of revolutions or the number of pe loadings, must be considered as being above normal. Consequently the abnormal numbe flexion/extension movements is defined as over and the axial loadings as peak overloading

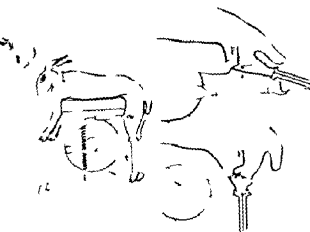


Figure 1 Left The mode of fixation of the animal on the specially constructed apparatus Upper right Flexion of the knee Lower right Extention of the knee with the mode of the delivered impact

MATERIAL AND METHODS

These are summarized in Table 1 Forty rabbits were divided into seven groups rabbits of Groups A B and C were subjecte 30, 60 and 120 minutes at 60 revolutions minute of the driving wheel (1800 3600 and 7 flexions and peak loadings in all) At the en each of the experiments the animals of t groups were killed immediately and the artic surfaces of the knee joints were examined scanning electron microscopy (SEM) biochemically In the three rabbits of Grou (7200 revolutions) only the articular car menisci and synovial membrane were exa for their prostaglandin (PGE) content mediately after completion of the experiment three rabbits of Group E were subjected t same experimental procedure as those Group C but were killed 1 3 and 7 days af completion of the experiment Only SEM c articular cartilage surface was done in this g

For the scanning electron microscope exa tion, the articular surface was immed dissected and fixed at the end of the experim critical point drying was done and then given conductive coats of carbon and according to a method described by Boyde & (1974). The specimens were examined photographed in a Cambridge Stereosca scanning electron microscope The pictu both knees were compared.

The biochemical examinations include analyses for prostaglandin E group (PGE)

Table 1 Summary of the investigation

Group	No of rabbits	Duration of experiment (minutes)	No of revolutions	Examination performed	Biochemical examination: cAMP in bone and cartilage	Biochemical examination: PGE in synovial fluid	Biochemical examination: PGF in cartilage menisci and synovia	Microscopical and X ray examination: SEM	Microscopical and X ray examination: Histology	Microscopical and X ray examination: X ray
A	8	30	1800	Immediate	+ (5 rabbits)	+ (5 rabbits)	–	+ (3 rabbits)	–	–
B	8	60	3600	Immediate	+ (5 rabbits)	+ (5 rabbits)	–	+ (3 rabbits)	–	–
C	8	120	7200	Immediate	+ (5 rabbits)	+ (5 rabbits)	–	+ (3 rabbits)	–	–
D	3	120	7200	Immediate	–	–	+ (3 rabbits)	–	–	–
E	3	120	7200	After 1 3 7 days	–	–	–	+ (3 rabbits)	–	–
F	6	30 min/day for 5 days	9000	After 75 days	–	–	–	–	+ (6 rabbits)	+ (6 rabbits)
G	6	30 min/day for 15 days	27000	After 85 days	–	–	–	–	+ (6 rabbits)	+ (6 rabbits)

synovial fluid, the articular cartilage, the menisci and the synovial membrane and (b) the estimation of cyclic 3′, 5′ adenosine monophosphate (cAMP) in the bones and cartilage For the former, the knee joints were dissected at the end of the experiments, the synovial spaces were rinsed with 0 5 cm^3 of cold 50 mM tris buffer at pH 7 0 and analysed for PGE content by radio-immuno assay (Bauminger et al 1973) The articular cartilage menisci and synovial membrane obtained from the three rabbits of Group D were homogenized in 50 mM tris EDTA buffer pH 7 0 and analysed for PGE content by the same method

For the estimation of cAMP, the bones on each side of the knee joints were immediately frozen in liquid nitrogen and cut transversely into 3 mm thick samples and pulverized in liquid nitrogen by a metal piston After adding the bone powder to distilled water, the mixture was boiled for 5 min in a salt bath (Shanfeld et al 1975) The samples were then further homogenized by an ultrathorax (Tp 18–10)

The cAMP content was estimated in the supernatant by the protein binding assay (Gilman 1970) As the samples from each rabbit were treated identically, the results obtained from the overuse and peak overloaded bones were compared with those obtained from the contralateral bones subjected to overuse only and expressed as the percentage of change

The rabbits in the groups F and G (six rabbits in each group) served for the estimation of the late changes in the articular cartilage and the bones. In these groups the experiment was run for a period of 30 min at 60 rev/min of the driving wheel each day for 5 and 15 days, 9000 and 27000 revolutions, respectively In between the experiments the rabbits were allowed to move freely in the cages. Care was taken to protect the protruding pins. Two separate small bandages were applied on each leg in such a way as to allow free movements of the joints. At the end of the experimental period the pins were removed and 10 weeks later, the animals were killed. High resolution roentgenograms of the knee joint were taken and thereafter the joint was examined histologically After decalcification a sagittal section of the joint was done and stained by haematoxylin eosin

RESULTS

Scanning electron microscopy (SEM)

The changes in the morphology of the articular surface seen in the knees which were

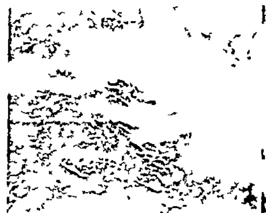


Figure 2 SEM of articular surface of a femoral condyle after 1 hour of overuse and peak overloading showing both undamaged regions and damaged ones containing debris (× 1680).

subjected to simultaneous overuse and peak overloading consisted of damage to the superficial layer, which was found to be detached exposing the collagenous matrix These changes occurred only when the experiment lasted at least 1 hour (3600 revolutions and loadings) At that time only a limited area was affected (Figure 2). The affected area was more extensive when the experiment lasted 2 hours (7200 revolutions and loadings) (Figures 3 4) The damage was even more pronounced when the knee was subjected to 7200 revolutions and loadings and examined after 3 or 7 days (Figure 5).

No such changes were seen in the contralateral joint submitted to overuse only (Figure 6)

It may therefore be concluded that peak overloading had long lasting and progressive physical effects, the initial damage giving but an incomplete picture of the later deterioration of the joint surface

Prostaglandin E group (PGE)

When the knees subjected to simultaneous overuse and peak overloading were examined after 2 hours of exercise (7,200 revolutions and loadings), the synovial fluid was found to



Figure 3 SEM of articular surfaces of a femoral condyle after 2 hours of overuse and peak overloading showing damage and abundant debris (× 1500)



Figure 5 SEM of articular surface taken 7 days after 2 hours of overuse and peak overloading The cellular layer of the articular surface is detached and the collagenous matrix is exposed Empty lacunae can be seen (× 15,000)

contain a five-fold increase in prostaglandin E, as compared with the contralateral knee (Figure 7). No significant increase of PGE was found after 30 or 60 min of exercise (1800 and 3200 revolutions and loadings) No significant changes in the amount of prostaglandin were found in the synovial membrane, the articular cartilage or the menisci of both knees.

Cyclic 3–5′ Adenosine Monophosphate (cAMP)

The knees subjected to simultaneous overuse and peak overloading showed a reduction of the cAMP content after 60 min of overuse and peak overloading (3600 revolutions), as compared with the other knee The reduction was more pronounced in

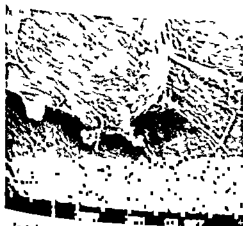


Figure 4 SEM of articular surface of a femoral condyle after 2 hours of overuse and peak overloading showing detail of a semi detached piece of debris (× 10 000)

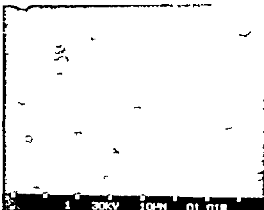


Figure 6 SEM of articular surface of a femoral condyle after 2 hours of overuse only showing a smooth undamaged surface (× 1500)

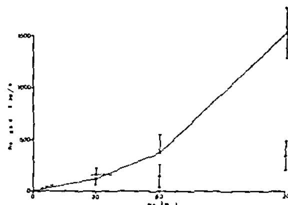


Figure 7 Accumulation of prostaglandins E series in the synovial fluid in overused knees (broken line) and overused and peak-overloaded knees (continuous line)

the subchondral bone and occurred first in the tibia and later in the femur There were no significant changes, regardless of the number of revolutions, either in the articular cartilage or in the cortical bone (Table 2)

X-ray

Flattening of the epiphysis, small bo cysts and osteophytes were found on th roentgenograms of knees subjected repeated simultaneous overuse and pe overloading (1800 revolutions and loadi per day for 15 consecutive days) (Figure Milder changes were seen when the e periments were repeated for 5 days only such abnormality was found in the co tralateral knees subjected to overuse only

Histology

Repeated simultaneous overuse and pe overloading (1800 revolutions and loadi per day for 15 days) resulted in cellul degeneration, disturbed arrangement of th cells with cluster formation and fibrillation the articular cartilage with penetration of th subchondral capillaries into the calcified la of the cartilage There was thickening of th subchondral bone with the presence

Table 2 The cAMP content in different anatomical areas of the knee The percentages have be calculated according to the following formula

$$\frac{cAMP\ left\ knee - cAMP\ right\ knee}{cAMP\ right\ knee} \times 100$$

(right knee = overuse only)
(left knee = overuse and peak overloading)

THE cAMP CONTENT OF ARTICULAR CARTILAGE, SUBCHONDRAL, SPONGIOUS AND CORTICAL BONE

Duration of the experiment	30 min		60 min	120 min
	$\bar{x}$	SE	$\bar{x}$ ± SE	$\bar{x}$ ± SE
Cortical bone	0 93%	8 87	13 45% ± 11 11	9 8% ± 10 41
Spongious bone	- 2 92%	9 04	- 2 69% ± 9 04	-32 0% ± 12 4%*
Subchondral bone	+ 3 25%	8 65	-12 84% ± 3 96*	-36 0% ± 2 21*
Cartilage	+ 4 10% ±	10 88	- 0 43% ± 14 79	- 1 25% ± 9 1
Cartilage	1 90%	7 95	7 01% ± 7 45	+ 7 25% ± 22 3
Subchondral bone	+ 0 06%	6 45	-42 9 % ± 3 12*	-49 33 ± 6 3*
Spongious bone	+ 3 81%	11 85	-33 52% ± 7 51*	25 13 ± 4 45*
Cortical bone	? 93%	8 72	+ 8 06% ± 9 23	+ 3 0 ± 9 64

*$p < 0.05$

Figure 8 Roentgenograms taken 10 weeks after 15 consecutive days of overuse (at left) and overuse and peak overloading (at right) of the knee The upper end of the tibia shows flattening of the medial part of the epiphysis with condensation of subchondral bone and cyst formation (arrow) in the peak overloaded knee



Figure 9 Sagittal section of a femoral condyle 10 weeks after 15 consecutive days of overuse and peak overloading showing fibrillated articular cartilage which becomes progressively thinner from left to right. The tidemark has advanced into the radial zone of the cartilage and there is increased subchondral vascularization (× 80)



Figure 10 Sagittal section of a femoral condyle 10 weeks after 15 consecutive days of overuse and peak overloading showing disorganization of cartilage cells and hypocellularity in the radial zone with empty lacuna The tidemark is broken and penetrated by blood vessels from subchondral bone The subchondral bone is thick and new lamellar bone has formed (× 300)



Figure 11 Articular cartilage from an overused knee 10 weeks after 15 days of exercise showing a normal arrangement of the cartilage in the various zones The tidemark is intact and there are no changes in the subchondral bone (×300)

lamellar bone parallel to the articular surface (Figures 9, 10) These changes, consistent with the pattern of osteoarthritis, were not found in the contralateral joint subjected to overuse only (Figure 11)

DISCUSSION

The fact that the observed changes occurred in knees subjected to simultaneous overuse and peak overloading but not in those subjected to overuse only permits the conclusion that it is the added peak overloading which is responsible for their occurrence These changes are twofold early physical and biochemical changes in the articular cartilage the subchondral bone and synovial fluid and late changes in the articular cartilage and subchondral bone consistent with osteoarthritis

With regard to the physical changes in the articular cartilage, there are three points which merit some emphasis —

1 The existence of a threshold below which no changes occur
2 The direct relation of the extent of damage to the duration of the insult
3 The progressive deterioration after cessation of the insult It may be presumed that the last two in particular may have an influence on the appearance of the late osteoarthritic changes.

Increased amounts of PGE have been found in the synovial fluid of patients with [illegible] septic arthritis and active rheum[illegible] arthritis (Velo et al 1973 Robinson & Levine 1974) Synovial cells derived from rheumatoid patients synthetize large quantities of PGE *in vitro* (Robinson et al 1975b Dayer et al 1977) The high levels of prostaglandins in the joints of such are believed to be one of the factors leading to cartilage destruction and bone resorption (Eisenbarth & Lebovitz 1974 Robinson et al 1975a Dietrich & Raisz 1975) However the role of prostaglandins in osteoarthritis is not yet established Our results may suggest that prostaglandins have an important role in the pathogenesis of osteoarthritis as a result of repetitive overloading Furthermore the relative effectiveness in patients with osteoarthritis of anti inflammatory drugs such as aspirin and indomethacin, which are potent prostaglandin synthetase inhibitors (Vane 1971, Ferreira et al 1971), can be explained on this basis.

The changes in cAMP content in the subchondral bone are more difficult to interpret Cyclic cAMP is thought to be the second messenger in regulating intracellular function as a consequence of the action of external stimuli, hormones in particular (Sutherland et al 1965) Lately it was suggested that cAMP may act as a mediator of the mechanical stimuli in bone and cartilage (Rodan et al 1975, Davidovitch & Shanfield 1976 Hazel et al. 1977) In addition intimate correlation exists between cAMP levels and proliferative activity of various cell types. Reduction in cAMP concentration was observed during mitotic activity of fibroblasts bone marrow and other cells (Otten et al 1971, Tieman & Herbert 1973, Oler et al 1973 Tell et [illegible] 1973) The reduction of the cAMP concentration found in the subchondral bone may express either a reaction to the mechanical stress or an increased mitotic activity However this reduction was specifically in the subchondral bone and not in the cartilage or cortical bone

This observation confirms the concept developed by Radin et al (1972, 1973) in which impact loading produced rapid changes in the subchondral bone, leading to bone stiffening through microfractures or bone resorption and new bone formation (Pugh et al 1974) This subchondral remodelling is assumed to initiate secondary changes in the articular cartilage (Johnson 1962)

The results of our experiments do not allow us to draw definite conclusions as to the initial factor It seems reasonable to assume that the damage to the cartilagenous surface and the biochemical changes in the subchondral bone may be simultaneous and that their cumulative effects lead to late osteoarthritic changes such as those seen in the groups of animals killed some time after completion of the experiments

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REFERENCES

Bauminger, S, Zor, U & Lindner, H R (1973) Radioimmunological assay of prostaglandin synthetase activity *Prostaglandins* 4, 313–322.

Bennet, G A. & Bauer, W (1937) Joint changes resulting from patellar displacement and their relation to degenerative joint disease *J Bone Jt Surg* 19, 667–682

Boyde A & Jones, S J (1974) Bone and other hard tissues. *Principles and techniques of scanning electron microscopy* Ed. Hayat, M A. van Nostrand Reinhold Company, New York

Crelin, E. S & Southwick, W O (1964) Changes induced by sustained pressure in the knee joint articular cartilage of adult rabbits. *Anat Rec* 149, 113–133

Dandovich, Z. & Shanfield, J (1976) Cyclic AMP levels in alveolar bone of orthodonticall treated cats. *Arch. Oral Biol.* 20, 567–574

Dayer, J M, Robinson, D R. & Krane, S M (1977) Prostaglandin production by rheumatoid synovial cells. *J exp Med* 145, 1399–1404

Dietrich, J W & Raisz, L G (1975) Prostaglandin in calcium and bone metabolism *Clin Orthop* 111, 228–237

Eisenbarth, G S & Lebovitz H E (1974) Prostaglandin inhibition of cartilage chondromucoprotein synthesis concept of intrinsic activity *Prostaglandins* 7, 11–20

Ferreira, S H, Moncada, S & Vane, J R (1971) Indomethacin and aspirin abolish prostaglandin release from the spleen *Nature New Biol* 231, 237–239

Gilman, A (1970) A protein binding assay for adenosine 3', 5'-cyclic monophosphate *Proc nat Acad Sci (Wash)* 67, 305–312

Harell, A, Dekel, S & Binderman, I (1977) Biochemical effect of mechanical stress on cultured bone cells *Calcif Tiss Res*, Suppl 22, 202–207

Hulth, A., Lindberg, L & Telhag, H (1970) Experimental osteoarthritis in rabbits Preliminary report. *Acta orthop scand* 41, 522–530

Johnson, L C (1962) Joint remodelling as the basis for osteoarthritis. *J Amer vet Ass* 141, 1237–1241

Murray, D G (1964) Experimentally induced arthritis using intra articular papain *Arthr and Rheum* 7, 211–219

Oler, A, Iannaccone, P M & Gordon, G B (1973) Suppression of growth of L cells in suspension culture by dibutyryl adenosine 3', 5' monophosphate *In vitro* 9, 35–38

Otten, J, Johnson, G S & Pastan, I (1971) Cyclic AMP levels in fibroblasts. Relationship to growth rate and contact inhibition of growth. *Biochem biophys Res Commun* 44, 1192–1198

Pugh, J W, Radin, E L & Rose, R M (1974) Quantitative studies of human subchondral cancellous bone *J Bone Jt Surg* 56-A, 313–321

Radin, E L., Paul, I L & Rose, R M (1972) Role of mechanical factors in pathogenesis of primary osteoarthritis *Lancet* i, 519–522

Radin, E L, Parker, H G, Pugh, J W, Steinberg, R S, Paul, I L & Rose, R M (1973) Response of joints to impact loading Relationship between trabecular microfractures and cartilage degeneration *J Biomech* 6, 51–57

Robinson D R, McGuire, M B & Levine, L (1975a) Prostaglandins in the rheumatic diseases *Ann N Y Acad Sci* 255, 318–329

Robinson D R, Smith, H, McGuire, M B & Levine, L (1975b) Prostaglandin synthesis by rheumatoid synovium and its stimulation by colchicine *Prostaglandins* 10, 67–85

Robinson, D R & Levine, L (1974)

Prostaglandin concentration in synovial fluid in rheumatic diseases. *Action of indomethacin and aspirin in prostaglandin synthetase inhibitors* Ed Robinson, H J & Vane, J R Raven Press, N Y

Rodan, G A, Bourret, L A., Harvey, A & Mensi, T (1975) Cyclic AMP and cyclic GMP—Mediators of the mechanical effect on bone remodelling *Science* 189, 467–469

Shanfeld, J, Shapiro, I & Davidovitch, Z (1975) The measurement of adenosine 3', 5', monophosphate in bone *Analyt Biochem* 66, 450–459

Simon S R, Radin, E L, Paul, I L & Rose, R M (1972) The response of joints to impact loading In vivo behaviour of subchondral bone *J Biomech* 5, 267–272.

Sutherland, E.W, Oye, I & Butcher, R W (1965) The action of epinephrine and the role of the adenyl cyclase system in hormone action *Recent Progr Hormone Res* 21, 623–646

Tell, G P E, Cuatreasas, P, Van-Wyk, J J, Hintz, R L (1974) Somatomedin [illegible] of adenylate cyclase activity in [illegible] membranes of various tissues *Science* [illegible] 312–314

Tisman, G & Herbert V (1973) Studies [illegible] effects of cyclic adenosine 3, 5 [illegible] phosphate in regulation of human [illegible] poiesis in vitro *In Vitro* 9, 86–91

Trias, A (1961) Effect of persistent pressure [illegible] the articular cartilage An experimental [illegible] *J Bone Jt Surg* 43-B, 376–386

Vane, J R (1971) Inhibition of prostaglandin synthesis as a mechanism of action for aspirin-like drugs *Nature New Biol.* 231, 232–23[illegible]

Velo, G P, Dunn C J, Giroud J P., Timsit J & Willoughby, D A (1973) Distribution of prostaglandins in inflammatory exudate J *Path* 111, 149–158

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EFFECTS OF OXYTETRACYCLINE ON THE MECHANICAL PROPERTIES OF BONE AND SKIN IN YOUNG RATS

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The influence of the tetracycline antibiotics on growing bones has been disputed In the present study 58 young male rats were given intraperitoneal injections twice a day for 2 weeks, half of the rats received oxytetracycline and the other half placebo The concentration of oxytetracycline in plasma was comparable with therapeutic levels in man Compared with the control animals the oxytetracycline rats had at the end of the medication period, a significantly lower weight (7 per cent) shorter bones (1–2 per cent) lower bending strength of both the tibia diaphysis (9 per cent) and the distal femur metaphysis (22 per cent) and even lower tensile strength of intact (17 per cent) and sutured (27 per cent) skin The effect of oxytetracycline seems to be reversible as no differences between the two groups could be detected 1–3 weeks after the end of medication

Key words bones, mechanical properties oxytetracycline plasma concentration, rats, skin, tensile strength tetracycline

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It is well established that tetracycline antibiotics are deposited in developing teeth, leading to discolouration and enamel hypoplasia These antibiotics are also known to deposit in growing bones, but their effect on bones is disputed Reduced bone growth (Cohlan et al. 1963, Yen & Shaw 1972) and increased bone fragility (Gudmundson 1971) have been observed, but there have also been reports of no impairment of growing bones by the tetracyclines (Chu et al 1963, Gruden 1973) To our knowledge, the effect of these antibiotics on the mechanical properties of skin has so far not been investigated

The purpose of the present study in rats was to assess the effect of oxytetracycline on

1 Weight gain and longitudinal bone growth.
2 Mechanical properties of a) Bones, b) Wounded and intact skin.

MATERIALS AND METHODS

Fifty-eight outbred male Wistar/Af/Han/Mol SPF rats were used At the start of the experiments the rats were 20 to 21 days old weighing from 32 to 37 g Five animals were kept in each cage and given water and Norwegian standard diet for rats *ad libitum* The rats were divided in two weight matched groups of 29 animals one oxytetracycline treated and the other control

The oxytetracycline treated rats received 2 8 mg oxytetracycline (Terramycin* Intravenous, Pfizer) in 0 5 ml water as intraperitoneal injections every twelfth hour for 14 days For practical reasons the amount of medicine given to each animal was constant throughout the medication period In the middle of the period 49 mg/kg was given twice a day The control animals received corresponding injections of the vehicle

The oxytetracycline concentrations were determined by the paperdisc method of AB-biodisk (Stockholm Sweden) utilizing *Bacillus cereus* (ATCC 11778) as test organism and

Prostaglandin concentration in synovial fluid in rheumatic diseases. *Action of indomethacin and aspirin in prostaglandin synthetase inhibitors* Ed Robinson, H J & Vane, J R Raven Press, N Y

Rodan, G A, Bourret, L A, Harvey, A & Mensi, T (1975) Cyclic AMP and cyclic GMP—Mediators of the mechanical effect on bone remodelling *Science* 189, 467–469

Shanfeld, J., Shapiro, I & Davidovitch, Z. (1975) The measurement of adenosine 3', 5', monophosphate in bone *Analyt Biochem* 66, 450–459

Simon, S R, Radin, L. L., Paul, I L & Rose R M (1972) The response of joints to impact loading In vivo behaviour of subchondral bone *J Biomech* 5, 267–272.

Sutherland, E. W., Oye, I & Butcher, R W (1965) The action of epinephrine and the role of the adenyl cyclase system in hormone action *Recent Progr Hormone Res* 21, 623–646

Tell G P E, Cuatrecasas, P., Van Wyk, J J Hintz, R L (1974) Somatomedin Inhibitic of adenylate cyclase activity in subcell. membranes of various tissues. *Science* 18[illegible] 312–314

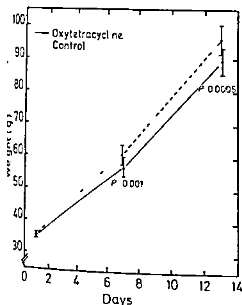
Tisman, G & Herbert, V (1973) Studies [illegible] effects of cyclic adenosine 3, 5 mon[illegible] phosphate in regulation of human hem[illegible] poiesis in vitro *In Vitro* 9, 86–91

Trias, A (1961) Effect of persistent pressure [illegible] the articular cartilage An experimental stud[illegible] *J Bone Jt Surg* 43-B, 376–386.

Vane, J R (1971) Inhibition of prostaglandin synthesis as a mechanism of action for asp[illegible] like drugs. *Nature New Biol.* 231, 232–235.

Velo, G P., Dunn, C J, Giroud, J P., Timsit, J & Willoughby, D A (1973) Distribution [illegible] prostaglandins in inflammatory exudate *J Path* 111, 149–158

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igure 2 *The weight gain in the oxytetracycline and in the control rats in the medication period (Median with 25 and 75 fractiles)*

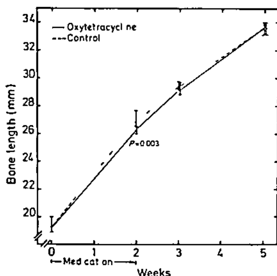


Figure 3 The longitudinal growth of the right tibia in the oxytetracycline and in the control rats (Median with 25- and 75 fractiles)

ESULTS

n the fifth and twelfth day of medication e plasma concentration of oxytetracycline as measured 2, 6 and 12 hours after the intraperitoneal injections The results are own in Table 1

The weight of the rats increased six times this 5 week experiment, from 35 to 215 g uring the first 2 weeks, i e, in the medication period, the growth was however, significantly lower for the oxytetracycline an for the control rats (Figure 2) In the last 3 weeks of the experiment there was no difference in weight between the two groups, as the oxytetracycline rats caught up with the control rats a few days after the end of the medication period.

Principally the same experience was gained when studying the length of the bones At the end of the medication period both tibia and femur were significantly shorter in the oxytetracycline than in the control group No difference was found after 3 and 5 weeks (Figure 3)

A corresponding difference was found in the bending strength of the bones in the two groups The distal femur metaphysis of the

ble 1 The plasma concentration of oxytetracycline on the fifth day (5 rats) and on the twelfth day (4 rats) of the medication (Median with 25 and 75 fractiles)

Day of medication	Dose mg/kg/12h	Plasma concentration (µg/ml) 2h after injection	6h after injection	12h after injection
5th	51	8 0 (8 0–9 3)	2 4 (1 9 2 6)	<1 0
12th	31	6 0 (5 3 6 8)	0 8 (0–1 6)	<1 0

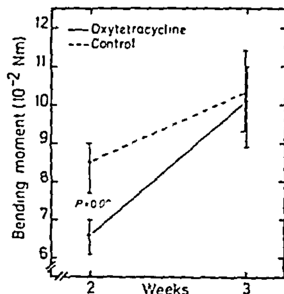


Figure 4 The bending moment necessary to produce fracture in the distal right femur metaphysis (3 mm proximal to the epiphyseal plate) in the oxytetracycline and in the control rats (Median with 25 and 75 fractiles)

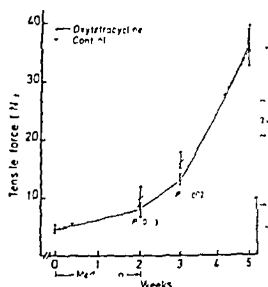


Figure 5 The tensile force necessary to pull apart the intact skin specimens from the oxytetracycline and from the control rats (Median with 25- and 75 fractiles)

oxytetracycline rats was 22 per cent weaker than the metaphysis of the control rats at the end of medication while no difference was observed later (Figure 4) After 2 weeks the bending strength in the middle of the tibia was also significantly less (9 per cent) in the oxytetracycline than in the control group and once again there was no difference after 3 and 5 weeks

Oxytetracycline was also found to influence the mechanical properties of skin The tensile strength of sutured skin specimens was 27 per cent less ($P=0.02$) in the oxytetracycline than in the control animals at the end of medication Also this parameter was equal in the two groups 1 and 3 weeks later The intact skin specimens from the oxytetracycline group were about 17 per cent weaker than the specimens from the control group both at 2 and 3 weeks, but no difference was found at 5 weeks (Figure 5)

DISCUSSION

In the present study oxytetracycline medication caused reduced weight gain reduced longitudinal bone growth increased bone fragility and reduced skin tensile strength.

The oxytetracycline dosage may perhaps seem to be a point of contention in this investigation The amount given in mg/kg day is true enough two to five times higher than the recommended maximum human dose (30 mg/kg/day) The plasma concentration is, however, by no means above human therapeutic levels. A single intravenous injection of 7 5 mg/kg oxytetracycline in man gives serum concentrations after 1–2 hours of 6–10 µg/ml, after 5–7 hours 4–5 µg/ml and after 11–12 hours still 2–3 µg/ml (Otten et al 1975). These concentrations are comparable to those in the present experiment and as 7 5 mg/kg is well within the recommended human dosage the concentrations in the present study correspond to human therapeutic levels. Comparing the dosage in the present investigation with that in others, however is difficult as the medicine is administered in different ways and the plasma concentration of tetracycline is reported in few publications

The influence of oxytetracycline in the present study seems to be reversible as no difference in growth or in strength could be

...ted 1 week after the cessation of medica-..., except for the tensile strength of intact ... from the oxytetracycline rats. This ...ameter was, however, equal in the two ...ups 3 weeks after the end of medication. ...erable inhibition of bone growth of ...acycline was also reported by Cohlan et ...(1963) in premature infants and by Yen & ...w (1973) in young monkeys. Gudmundson ...71), however, observed increased fragility ...at femur and tibia for 90 days after only 1 ...k of intramuscular injections of oxy-...acycline (10 mg/kg/day).

The possibility may be considered that the ...uced growth observed in the oxy-...racycline rats during the medication was a ...sequence of impaired intestinal function, ...sed either by disturbance of intestinal flora ... by an inflammatory reaction in the ...itoneal cavity after the oxytetracycline in-...ions. In accordance with the latter, at the ... of medication, the peritoneum was found ...e more reddish in the oxytetracycline than ...the control rats, but no signs of inflamma-...n were observed later in either group. ...wever, Cohlan (1963) and Yen & Shaw ...72) also reported reduced growth and they ... not use intraperitoneal administration of ...medicine.

At the end of medication the femur and ...ia in the oxytetracycline rats were ...rter – 1 and 2 per cent, respectively – ...n the bones in the control rats, while the ...ding strength of the tibia diaphysis was ...luced by 9 per cent and that of the distal ...nur metaphysis by 22 per cent compared ...th the bones of the control animals. This ...ay indicate that the bone strength is ...duced to a greater extent than the ...ngitudinal bone growth. Why then ...ould the reduction in bone strength be ...re pronounced in the femur metaphysis ...an in the tibia diaphysis? The explanation ...ay be found in the mode of growth of the ...g bones. As the longitudinal growth of ...th tibia and femur takes place mainly in ...e epiphyseal plates near the knee and as the ...mur growth during the medication was ...out 6mm, all the tested metaphyseal bone material (3 mm proximal to the epiphyseal plate) was produced under the influence of oxytetracycline. In the tibia diaphysis, however, only parts of the tested bone material were made under oxytetracycline influence, viz., the shell of periosteum derived bone. If oxytetracycline really causes production of a weaker bone material it would be expected that the metaphyseal bone would be more affected than the diaphyseal bone, as the former is entirely produced under the influence of oxytetracycline while the latter only partly.

Also the reduction in the tensile strength of both intact and sutured skin (17 and 27 per cent, respectively) from the oxytetracycline rats appears to be greater than the general growth inhibition (weight difference of 9 per cent in the two groups) can explain.

In what way the oxytetracycline impairs the mechanical properties of both bone and skin remains unanswered. As collagen is the dominant organic component both in bone and skin, the influence of oxytetracycline on the biosynthesis and maturation of collagen seems extremely interesting in this context.

REFERENCES

Chu, E., O'Hara, A. D. & Kelsey [illegible] Relationship of growth [illegible] premature infants to the [illegible] tetracycline. *Antimicrob. Agents* [illegible] 3, 753–755.

Cohlan, S. Q., Bevelander, [illegible] (1963) Growth inhibition [illegible] receiving tetracycline. [illegible] 105, 453–461.

Diem, K. & Lentner, C. [illegible] Geigy. *Scientific Tables* [illegible] Ltd. Basle, 810 pp.

Engesaeter, L. B., [illegible] (1978) Method [illegible] perties of the rat [illegible] 512–518.

Gruden, N. (1971) [illegible] in relation [illegible] tetracycline [illegible]

Gudmundson [illegible] fragility [illegible] 284–289.

Jalling, B, Malmborg, A-S, Lindman, A & Boréus, L. O (1972) Evaluation of a micromethod for determination of antibiotic concentrations in plasma *Europ J Clin Pharmacol* 4, 150–157

Otten, H, Plempel, M & Siegenthaler, W (eds.) (1975) *Antibiotika Fibel* 4th ed. pp 319–361 Georg Thieme Verlag, Stuttgart.

Yen, P K-J & Shaw, J H (1972) Preliminary study of inhibitory effects of tetracyclines on membranous bone growth in Rhesus monkeys. *J dent Res* 51, 1651–1657

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CONTENT AND SYNTHESIS OF NUCLEIC ACIDS IN THE CARTILAGE IN CHONDROMALACIA PATELLAE

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The content and the synthesis of nucleic acids in chondromalacian, osteoarthritis and normal cartilage was compared The chondromalacian cartilage differed from osteoarthritis in that the content of nucleic acids was less Also, the cell density was less in chondromalacian than in normal cartilage as opposed to previous findings in osteoarthritis The synthesis of [illegible] less than [illegible] teoarthritic cartilage

Key words chondromalacia patellae, articular cartilage, autoradiography, nucleic acids

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Chondromalacia patellae is defined as a degenerative condition of the articular cartilage of the patella Usually, it is seen in young adults but it may also occur in later life The etiology is debatable Trauma, incongruity and nutritional causes have been discussed. There are numerous biochemical studies of osteoarthritis, whereas studies of chondromalacia patellae have been noticeably few In an earlier investigation (Shoji et al 1974) no differences in the DNA content compared with normal articular cartilage were found, nor any differences in the content of hexosamine, non-collagenous protein, acid phosphatase or beta-glucuronidase However, the content of Cathepsin D was found to be significantly elevated in both chondromalacia and osteoarthritis. Owing to these results the authors suggested that chondromalacia seemed to be a disease developing into osteoarthritis

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The purpose of the present study was to compare parameters of nucleic acid content and synthesis in normal joint cartilage, chondromalacian cartilage and the cartilage of joints with osteoarthritis

MATERIAL AND METHODS

Samples of the patellar lesions in 28 patients with chondromalacia patellae of grade I–III (Outerbridge 1961) were obtained in conjunction with surgery The age range of the patients was 15–45 (average 28) In nine patients, cartilage was also taken from macroscopically normal parts of the patellar joint surface and in eight from a non-weight bearing part of the femoral condyles also of normal appearance In addition, cartilage biopsies were obtained from 19 individuals with the same range of age in conjunction with arthrotomies for removal of ruptured semilunar cartilages. In none of the latter patients were there any macroscopic signs of degenerative joint disease including chondromalacia patellae Finally, cartilage samples were obtained from the femur condyles in eight patients with osteoarthritis of the knee in conjunction with surgical reconstruc-

tion of the joint In these cases the cartilage was taken from the weight-bearing part of the femur condyle joint surface The age of this latter group ranged from 29 to 69 with an average of 53 The 29-year-old was a man with post traumatic osteoarthritis of the knee, otherwise the osteoarthritis was classified as primary

The specimens were divided into two pieces, one for biochemical investigation and one for histologic and autoradiographic studies. They were immediately placed in 10 ml of Eagle's solution at 37°C containing 50 μ Ci ^{3}H thymidine or ^{3}H-uridine and shaken for 4 hours.

The specimens for the histologic-autoradiographic study were washed in physiologic saline solution and fixed in 10 per cent neutral, buffered formalin, decalcified in EDTA and embedded in paraffin The histologic specimens were stained with hematoxylin-eosin, with Safranin-O and toluidine blue

In seven of the patients with chondromalacia patellae the abundance of chondrocytes was estimated in a) areas of chondromalacia b) patellar articular cartilage of normal appearance and c) condylar cartilage also of normal appearance In each sample, five fields (0 5 × 0 5 mm) were selected at random and counted The average variation within each sample was 11 per cent (c/v).

In all but the samples from osteoarthritis cases, autoradiographs of routine histologic sections, 5 μ thick, were prepared according to the dipping method with Ilford K2 liquid emulsion After 2 and 4 weeks exposure the autoradiographs were developed in Gevaert X-ray developer G 230 and fixed in Gevaert X ray fixer G 305 The sections were stained through the emulsion with Mayer's hematoxylin The specimens for the biochemical study were placed in acetone after shaking The aterial was weighed (dry weight). The cartilage was placed in a mortar covered with liquid nitrogen and pulverized It was then homogenized in 6 ml 10 per cent TCA (trichloroacetic acid) and the acid soluble nucleotides were separated by centrifugation. The precipitate was washed twice each time with 6 ml TCA The insoluble residue was treated with 5 ml of 0 3 M potassium hydroxide for 18 hours at 37°C to hydrolyze RNA, which was thereby brought into solution The solution was adjusted to pH 7 by the addition of 70 per cent perchloric acid Five ml of 5 per cent TCA was added to the neutral solution This resulted in precipitation of protein and DNA which were separated from the solution by centrifugation and washing of the precipitate three times, each time with 5 ml of 5 per cent TCA

RNA and DNA in the separated fractions were determined with the orcinol reaction (Mejbaum 1939) and the Ceriotti procedure (Ceriotti 1952) respectively The separation of RNA and DNA was checked in all experiments by applying both reactions to the RNA as well as to the DNA fraction The determinations were carried out in duplicate and the average used for further calculation

Each sample was assayed separately for radioactivity (^{3}H thymidine or ^{3}H-uridine) after suspension in 10 ml of Instagel (Packard), using two-channel Packard Tricarb liquid scintillation spectrometer The results were recorded as counts per milligram of dry weight per minute

RESULTS

No labeled chondrocytes or *microscopic* changes were found in the control specimens In the chondromalacian cartilage degenerative changes were seen with flaking of the superficial layer and sometimes fibrillation down to the columnar layer (Figure 1) Sometimes the superficial and also the transitional layers were loose with sparse staining of the matrix In some slides, fibrillation of the columnar layer as well as chondrocyte death and clustering were found similar to the findings in osteoarthritis, and in some blister formation in the superficial and transitional layers (Figure 2). After staining with Safranin-O and toluidine blue the matrix was less stained in the slides with degenerative changes. The chondrocytes were significantly less abundant in the chondromalacian cartilage as compared with normal patellar and condylar cartilage (Table 1). No labeled chondrocytes were found in the cartilage from patients with chondromalacia.

The content of DNA was significantly decreased in the chondromalacian cartilage as compared with normal cartilage (Table 2). Similar tendencies were found when the chondromalacian cartilage was compared with normal cartilage from the same patella or with femoral condyle cartilage from the same joint (Tables 4 and 6) The DNA content was significantly greater in osteoarthritis cartilage than in chondromalacian cartilage (Table 8) but not quite significantly



...ure 1 Section of chondromalacian cartilage ...th fibrillation. Note the scarcity of chondrocytes ...bjective × 6.3 hematoxylin eosin)



Figure 2 Section of chondromalacian cartilage with blister formation in the superficial and transitional layers (Objective × 6.3 hematoxylin eosin)

Table 1 Number of chondrocytes per mm² in chondromalacian cartilage as compared with normal patellar and condylar cartilage

Chondromalacian cartilage		Normal patellar cartilage		Normal condyle cartilage	
n	av ± s.d	*n*	av ± s.d	*n*	av ± s.d
7	164 ± 35	7	296 ± 84	7	306 ± 66
	0.01 > *P* > 0.001			*P* > 0.1	
			P > 0.001		

...le 2 *Nucleic acid content in patella cartilage of patients with chondromalacia patellae* (...ndromalacia) *and in non-weight bearing condylar cartilage obtained in conjunction with meniscectomy (control)*

		γ DNA/mg	γ RNA/mg	γ RNA/γ DNA
...ndromalacia	(*n* = 28)	2.5 ± 1.3	4.5 ± 2.4	2.6 ± 2.9
...trol	(*n* = 19)	4.0 ± 2.0	7.3 ± 3.2	2.2 ± 0.8
		0.01 > *P* > 0.001	0.01 > *P* > 0.001	—

...le 3 *Nucleic acid synthesis in patella cartilage of patients with chondromalacia patellae* (...ndromalacia) *and in non-weight bearing condylar cartilage obtained in conjunction with meniscectomy (control)*

	CPM DNA/ mg	CPM DNA/ γ DNA	CPM RNA mg	CPM RNA/ γ DNA	CPM RNA/ γ RNA
...ndromalacia (*n* = 28)	88 ± 57	36 ± 26	695 ± 450	410 ± 420	152 ± 86
...trol (*n* = 19)	65 ± 33	19 ± 11	1217 ± 689	381 ± 238	184 ± 113
	0.1 > *P* > 0.05	0.05 > *P* > 0.01	0.01 > *P* > 0.001	—	—

Table 4 Nucleic acid content in the cartilage of chondromalacian lesions (chondromalacia) and in cartilage of normal macroscopic appearance (control) from the same patella

Cartilage		µg DNA/mg	µg RNA/mg	µg RNA/µg DNA
Chondromalacia	(n = 9)	2.9 ± 1.2	6.1 ± 1.8	2.5 ± 0.9
Control	(n = 9)	4.8 ± 2.2	8.5 ± 2.9	2.0 ± 0.9
		0.05 > P > 0.01*	0.05 > P > 0.01*	—

* t test of pairs.

Table 5 Nucleic acid synthesis in the cartilage of chondromalacian lesions (chondromalacia) and cartilage of normal macroscopic appearance (control) from the same patella

Cartilage		CPM DNA/ mg	CPM DNA/ µg DNA	CPM RNA/ mg	CPM RNA/ µg DNA	CPM RNA/ µg RNA
Chondromalacia	(n = 9)	134 ± 57	49 ± 35	1205 ± 428	537 ± 237	216 ± 53
Control	(n = 9)	131 ± 100	27 ± 15	1089 ± 232	263 ± 72	166 ± 101
		—	0.1 > P > 0.05*	—	0.01 > P > 0.001*	—

* t test of pairs.

Table 6 Nucleic acid content in the patella cartilage of patients with chondromalacia patella (chondromalacia) and in cartilage of normal macroscopic appearance (control) from the femoral condyle of the same joint

Cartilage		µg DNA/mg	µg RNA/mg	µg RNA/µg DNA
Chondromalacia	(n = 8)	2.6 ± 0.7	6.1 ± 1.9	2.6 ± 0.9
Control	(n = 8)	4.2 ± 2.1	9.0 ± 4.8	2.6 ± 1.7
		0.1 > P > 0.5	0.2 > P > 0.1	—

Table 7 Nucleic acid synthesis in the patella cartilage of patients with chondromalacia patella (chondromalacia) and in cartilage of normal macroscopic appearance (control) from the femoral condyle of the same joint

Cartilage		CPM DNA/ mg	CPM DNA/ µg DNA	CPM RNA/ mg	CPM RNA/ µg DNA	CPM RNA/ µg RNA
Chondromalacia	(n = 8)	131 ± 60	52 ± 36	1198 ± 457	567 ± 234	210 ± 68
Control	(n = 8)	128 ± 69	32 ± 15	1175 ± 211	327 ± 125	513 ± 1107
		—	0.2 > P > 0.1*	—	0.05 > P > 0.01*	—

* t test of pairs.

Table 8 *Nucleic acid* content *in the cartilage from the femoral condyle of patients with osteoarthritis of the knee (osteoarthritis) and in chondromalacian lesions of patients with chondromalacia patellae (chondromalacia)*

Cartilage		µg DNA/mg	µg RNA/mg	µg RNA/µg DNA
Osteoarthritis	($n=8$)	5 7 ± 2 1	12 3 ± 3 4	2 6 + 1 3
Chondromalacia	($n=28$)	2 5 ± 1 3	4 5 ± 2.4	2 6 ± 2 9
		0 001 > P	0 001 > P	—

Table 9 *Nucleic acid* synthesis *in the cartilage from the femoral condyle of patients with osteoarthritis of the knee (osteoarthritis) and in chondromalacian lesions of patients with chondromalacia patellae (chondromalacia)*

Cartilage	CPM DNA/ mg	CPM DNA/ µg DNA	CPM RNA/ mg	CPM RNA/ µg DNA	CPM RNA/ µg RNA
Osteoarthritis ($n=8$)	222 ± 264	31 ± 14	1355 ± 562	271 + 144	124 ± 81
Chondromalacia ($n=28$)	88 ± 52	36 + 26	695 ± 450	410 + 420	152 ± 80
	0 05 > P > 0 01	—	0 01 > P > 0 001	—	—

creased in osteoarthritis cases as compared with the 19 controls (0 1 > P > 0 05) (Tables and 8)

The RNA content was reduced in chondromalacian cartilage both in comparison with the control patients and with the cartilage of normal appearance in the same joint. When corrected for the DNA content, however, there were no differences in the RNA concentrations (Tables 2, 4 and 6)

The DNA synthesis, related to the DNA concentration, was significantly increased in chondromalacian cartilage as compared with control cartilage (Table 3) This tendency was contradicted by the comparison with cartilage samples from the same joint (Tables and 7) However, per unit tissue, the DNA synthesis did not significantly differ between control and chondromalacian cartilage and identical when a comparison was made between normal and chondromalacian cartilage in the same joint (Tables 3, 5 and 7) comparison with osteoarthritis there was difference in DNA synthesis except when related to the amount of tissue (Table 9) when corrected for the DNA content there no difference

The *RNA synthesis* was about half in chondromalacia as compared with controls when related to the amount of tissue (Table 3) However, when corrected for the DNA concentration, there was no significant difference When, on the other hand, the data were compared between chondromalacian cartilage and cartilage of normal appearance within the same joint there was a significant increase To summarize chondromalacian cartilage demonstrated the highest rate of synthesis of RNA, whereas osteoarthritis in this study represented the lowest value with the control data in an intermediate position

DISCUSSION

The histological changes in osteoarthritis are well known and have been described by Collins (1949) and others.

In chondromalacia patellae, microscopic degenerative changes of the articular cartilage were found similar to those in osteoarthritis, with flaking of the cartilage surface and fibrillation (Figure 1) sometimes down to subchondral bone. As an expression of the

degeneration the ground substance was often less stainable with Safranin-O and toluidine blue in chondromalacia thus indicating a loss of glycosaminoglycans from the cartilage matrix changes similar to those in osteoarthritis

Goodfellow et al (1976) described fasciculation of the cartilage of the patella in young people suffering from intractable patello-femoral pain They also found an intermediate stage (between fasciculation stages 1 and 2) with blistering of the cartilage This was confirmed in our investigation where blistering was found especially in the *superficial and transitional layers (Figure 2)*

In earlier investigations an increased thickness of the cartilage was found in human osteoarthritis (Meachim & Collins 1962) In comparison with normal articular cartilage from the patella or from the femoral condyle there were less chondrocytes in chondromalacian cartilage According to Freeman (1973) there is an approximately inverse relationship between cell density and cartilage thickness We could not find any difference between normal cartilage from the patellae and cartilage from the femoral condyle either histologically or biochemically In earlier investigations it has been shown that mitoses of the chondrocytes indicating a higher DNA synthesis are found in degenerated articular cartilage from humans and animals (Hulth et al 1972, Telhag 1972) In chondromalacia tellae no thymidine-labeled chondrocytes were seen either as single chondrocytes, or in so-called clusters In osteoarthritis the DNA synthesis is increased (Mankin & Lippiello 1970 Mankin et al 1971) In the present study the same was found to occur in *chondromalacian cartilage but not* to a sufficient extent to label the chondrocytes.

Shoji et al (1974) found that the amount of DNA in chondromalacian cartilage compared with normal cartilage was unchanged In the present investigation a significantly decreased content of DNA was found in chondromalacian cartilage This is in agreement with the decreased chondrocyte density As reported in the past (Mankin & Lippiello 1970 Telhag & Gudmundson 1972) the DNA content in osteoarthritis as compared with normal cartilage is unchanged but in the present study there was a significant increase in osteoarthritis cartilage compared with chondromalacian

The RNA content has not previously been determined in chondromalacian cartilage We found a reduced quantity of RNA per amount of tissue as compared with normal cartilage. In relation to the DNA content the quantity of RNA was unchanged This is in agreement with the reduced cell density in chondromalacian cartilage found histologically

In a recent study the RNA synthesis in human osteoarthritis cartilage was not found to differ significantly from that of normal articular cartilage (Mankin & Lippiello 19 0). Mankin & Laing (1967) demonstrated a decreased synthesis of RNA in osteoarthritis cartilage from dogs which is in agreement with the findings in rabbits by Telhag & Gudmundson (1972) In the present study no significant difference was found in the RNA synthesis in chondromalacian cartilage as compared with normal cartilage When comparing cartilage from chondromalacian lesions and cartilage of normal appearance within the same joint there was an increase in the synthesis.

In the present investigation some factors indicate that chondromalacia patellae is a different disease from osteoarthritis viz., the reduced chondrocyte density the absence of thymidine labeled chondrocytes and the concentration of nucleic acids which is low as compared with normal articular cartilage as well as osteoarthritis cartilage

REFERENCES

Ceriotti G (1952) A microchemical determination of desoxyribonucleic acid *J biol Chem* 198 297–303

Collins, D H (1949) *Pathology of articular and spinal diseases* Williams and Wilkins Co. Baltimore

Freeman M A R (1973) *Adult articular cartilage* p 78 Sir Isaac Pitman and Sons Ltd

Goodfellow J., Hungerford D S & Woods, C (19 6) Patello-femoral joint mechanics and pathology 2. Chondromalacia patellae *J Bone Jt Surg* 58 B 291–299

Hulth, A., Lindberg L. & Telhag H (1972) Mitosis in human osteoarthritic cartilage *Clin Orthop* 84, 197–199

Mankin, H J & Laing P G (1967) Protein and ribonucleic acid syntheses in articular cartilage of osteoarthritic dogs *Arthr and Rheum* 10, 444–450

Mankin, H. J & Lippiello L (1970) Biochemical and metabolic abnormalities in articular cartilage from osteo-arthritic human hips. *J Bone Jt Surg* 52-A 424–434

Mankin, H J Dorfman, H, Lippiello L & Zarins, A. (1971) Biochemical and metabolic abnormalities in articular cartilage from osteo-arthritic human hips II Correlation of morphology with biochemical and metabolic data *J Bone Jt Surg* 53-A 523–537

Meachim G & Collins D H (196? ... counts of normal and osteoarthritic art ... in relation to the uptake of sulphate ... vitro *Ann rheum Dis* 21, 45 50

Mejbaum, W (1939) Uber die Bestimmung kl... n Pentosemengen inbesonder in Derivaten de Adenylsaure *Z Physiol Chem* 258, 117–1?0

Outerbridge, R E (1961) The etiology of chondromalacia patellae *J Bone Jt Surg* 43-B 752–757

Shoji H, Sakai S & Granda I L (1974) Chondromalacia patellae Histologic and biochemical aspects. *N Y St J Med* 74, 507–510

Telhag H (1972) Mitosis of chondrocytes in experimental "osteoarthritis in rabbits. *Clin Orthop* 86, 224–229

Telhag H & Gudmundson C (1972) Nucleic acids in degenerative joint disease An experimental study in rabbits. *Clin Orthop* 88, 247–251

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OSTEOMYELITIS AFTER OPERATIVE FRACTURE TREATMENT

A Report of 62 Cases Treated with Radical Surgery and Lincomycin (Lincocin®)

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During the years 1967–1975 a total of 62 patients were treated for postoperative osteomyelitis. The lower extremities had been fractured in 89 per cent of the cases and 54 per cent were closed injuries. The fractures, mostly caused by traffic accidents and falls, had been immobilized by plates in 30 and by intramedullary nails or pins in 25 patients.

Staphylococcus aureus was cultured in 80 per cent, 68 per cent of them were resistant to penicillin, but in 84 per cent the organisms were highly lincomycin sensitive and only three patients with four osteomyelitic lesions presented lincomycin resistance

The treatment consisted chiefly of sequestrectomies and saucerizations supported by 3–12 months of lincomycin treatment In 30 operations a closed irrigation-suction technique was used perfusing the wound with lincomycin solution Stable implants should be left in place until the fracture is clinically solid whereas unstable osteosyntheses should be replaced by rigid internal or extraskeletal fixation

At follow-up, the results were judged as good in 74 per cent fair 8 per cent and poor 18 per cent The amputation rate was 13 per cent

Plates should not be used in the treatment of comminuted tibial fractures with considerable soft tissue damage

Key words post-traumatic osteomyelitis operative procedures closed irrigation suction drainage, lincomycin treatment osteosynthesis of fractures, osteomyelitis, predisposing factors

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Osteomyelitis following fracture surgery implies a serious complication which prolongs the treatment and considerably increases the disability of the patient

This report concerns the results and some essential points in the treatment of chronic osteomyelitis after fracture surgery It also reflects some of the features of the primary treatment which favour the development of osteomyelitis Eighteen patients included in the present series have been reported earlier (Paus 1971).

MATERIAL AND METHODS

During the period 1967–1975, a total of 62 patients, 51 men and 11 women with 63 surgically treated fractures were treated for postoperative osteomyelitis at Martina Hansens Hospital Hip infections after osteosynthesis for

...oral neck and pertrochanteric fractures were ...luded from the material.

There was a preponderance of men between 20 ...d 50 years of age (mean age 38 years) with ...ffic and occupational accidents while the ...men (mean age 48 years) usually sustained ...ur fractures at an older age as the result of a ...l.

The accidents could be classified as 28 road ...idents, 21 falls, 7 occupational accidents, 4 ...orts injuries and 2 shooting injuries.

In agreement with other publications the osteo...yelitis was located in the femur and the tibia in ... per cent of the cases (Table 1)

The records and X-rays from the hospitals ...ere the primary treatment was given were reviewed with particular attention being paid to the type of osteosynthesis (Table 2) and the postoperative occurrence of osteomyelitis (Table 3) Half of the operations were performed as emergencies within 24 hours of the accident, the rest were delayed from 2–30 days Table 3 reveals that half of the infections developed within 2 weeks and 40 per cent were delayed more than 2 months

Seventy-five per cent of the fractures were associated with extensive damage to skin and soft tissues, and 33 per cent of the operations involved peroperative technical difficulties. Half of the fractures were stable postoperatively, 70 per cent of the closed and 32 per cent of the open fractures, respectively

...ble 1 *Localization and type of fracture in 63 ...ctures with osteomyelitis after osteosynthesis*

	Closed	Open		
...mur	14	10	89	per cent
...ia	11	15		
...lleolus	3	1		
...caneus	1			
...refoot		1		
...meral neck	3		11	per cent
...meral shaft		1		
...tebrachium		1		
...dius	2			
	34 (54 per cent)	29 (46 per cent)		

Follow-up examination

All the 62 patients were examined clinically and roentgenologically 3 months – 10 years after the last operation, the average observation period being 6 5 years Two patients with mainly ischaemic crural problems were followed for only 9 months whereas the remaining 60 patients were observed for a period of more than 2 years

One patient with a previously infected malleolar fracture died from cardiac failure in 1970 the postmortem examination revealed a poorly healed osteomyelitis. This patient is included in the material

At follow-up, the state of the patients was classified according to the following criteria

Good No clinical or roentgenological signs of osteomyelitis over the previous 2 years ≤10 per cent anatomical invalidity, normal sedimentation rate, normal or slightly reduced function, normal working ability

Table 2 Primary fracture treatment in 63 fractures (62 patients) complicated by osteomyelitis

		Number	Per cent
...ate		30	48
...tramedullary nail	8		
+ Cerclage	4		
+ Parham's band	2	14	22
...ushpin	7		
+ Cerclage	2		
+ Parham's band	1		
+ Screws	1	11	17
...rews	3		
+ Cerclage	2	5	8
...rclage or Parham's band		2	3
...lmer's pin + bone transpl		1	2

Table 3 Time of manifestation of osteomyelitis in 63 fractures treated with osteosynthesis

	Number	Per cent
< 2 Weeks	33	52
3rd Week – 1st Month	5	8
2nd Month – 6th Month	19	30
> 1/2 Year	6	10

Table 4 Duration of lincomycin treatment in patients with osteomyelitis after osteosynthesis

		Number	Per cent
< 3	Months	6	11
3–6	"	15	32
6–12	"	22	51
> 12	"	4	6

Fair Recurrence of osteomyelitis with or without minimal drainage, 10–25 per cent anatomical invalidity, reduced function

Poor Persistent drainage, pseudarthrosis, amputation of femur or tibia, > 25 per cent anatomical invalidity, considerably reduced function, disability insurance only owing to sequelae following osteomyelitis.

The groups "Good" and "Fair" constituted satisfactory results. All the criteria for a classification of "Good" needed to be fulfilled before the patient was placed in this group while only one was necessary in the groups "Fair" and "Poor"

TREATMENT OF OSTEOMYELITIS

The mean duration of osteomyelitis was 2 years (range 1 month – 23 years), and on admission to our department 90 per cent of the infections presented discharging fistulas whereas the remaining were temporarily dry After discontinuation of any antibiotic drug and no medication for about 1 week, new specimens for bacteriological growth were taken and sensitivity tests were carried out in all patients with fistulas and repeated later at regular intervals.

Staphylococcus aureus was cultured in 80 per cent (50/62), 68 per cent (34/50) of them were penicillin resistant but in 84 per cent (42/50) the organisms were highly lincomycin (Lincocin®) sensitive and only three patients with four osteomyelitic lesions (8 per cent) presented lincomycin resistance Lincomycin sensitivity tests were not performed in the remaining four patients (8 per cent) Phage typing was done only in about one-third of the cases

Thus, the lincomycin treated group comprised the 42 patients with high lincomycin sensitivity three patients with no bacterial growth in spite of several cultures, and two patients with highly lincomycin-sensitive strains of bacillus and Gram-positive anaerobic rods respectively

Table 4 demonstrates that more than half of the lincomycin-treated cases were given this drug for more than 6 months The drug was usually instituted a few days before operation in doses of 500 mg four times a day and continued unt about 4–5 weeks after healing and then reduce to 500 mg two or three times a day

The only side effect was a mild transie looseness of the stools which occurred in patients and did not necessitate discontinuation the drug The three patients with lincomyc resistance and the *four* who were not give lincomycin sensitivity tests, and four othe [illegible] after one yea [illegible] while the remaining four received no antibioti therapy

The surgical procedures used in our 62 patie are summarized in Table 5 In 30 operations wit stable mechanical conditions, mostly in t extremities, a closed irrigation suction techniqu was used with polyethylene tubes of 6–8 mm diameter, perfusing the wound with 0.4 per cen lincomycin solution An irrigation of 1000 m Ringer's or physiological saline solution with 60 mg (4 ml) lincomycin lasted from 4–7 days, an the amount of liquid used was 1000–1500 ml pe 24 hours.

The mean period of stay at the primary hospitals was 60 days and in our department 13 days, i e, a total mean hospitalization period of months.

RESULTS

The results were recorded as follows

Good – 74 per cent (46/62)
Fair – 8 per cent (5/62)
Poor – 18 per cent (11/62)

At the time of follow-up, there were no cases of pus secretion or pseudarthrosis and none of the patients were receiving any form of antibiotic therapy The 47 patients treated with lincomycin did not complain of side effects after its withdrawal The results were significantly better among the 33 cases with

Table 5 Operative treatment of osteomyelitis after osteosynthesis in 62 patients with 63 fractures

		Number
...ucerization	50	
+ Hoffmann's apparatus	2	
+ bone transpl	1	53
...estrectomy/removal of metal implant	3	
+ Osteosynthesis	2	5
osteosynthesis		2
...oval of metal implant	19	
Hoffmann's apparatus	1	20
...erization	12	
bone transplantation	6	
+ cross-leg/Hoffmann's app	1	19
...darthrosis operation /bone transpl	10	
Osteosynthesis	2	12
...dart. op./inlay of elec. stimulator		1
...utation		8
...tic procedure (split skin graft, ...oss-leg with delay skin tube)		22
		142

Table 6 Working capacity at follow-up of 62 patients with osteomyelitis after osteosynthesis*

	Number	Per cent
...al working capacity	41	66
...pension (normal daily activity)	5	8
...bility pension owing to osteomyelitis alone	9	15
...bility pension owing to osteomyelitis and other diseases	3	5
...bility pension prior to injury	3	5

...e patient had died

...cultures of *staphylococcus aureus* (31 .../1 fair/6 poor) as compared with 9 cases ...lincomycin resistant mixed infections (2 ...1 fair/6 poor)

...wever, amputations had to be performed ...ght cases (13 per cent), three poorly ...d infections with hip, shoulder and ankle ...damage respectively needed secondary ...odeses and two angular deformities ...red corrective osteotomies. The osteo... ...itis healed without removal of metal ...ants in only four patients.

...thological fractures occurred in six ...(10 per cent) and two of them belonged ...e amputation group In the initial osteo... ...eses three open transverse tibial shaft ...two closed transverse femoral shaft fractures were fixed with plates and one open transverse humeral shaft fracture was nailed by one Rushpin

Before and after the treatment at our hospital the mean sedimentation rate was 32 mm/hour (range 25–115) and 9 mm/hour (range 2–40), respectively

Table 6 shows the working capacity at the follow-up examination and it is pointed out that two-thirds of the patients are doing full-time work, seven of them after having been through a rehabilitation programme

DISCUSSION

Pathophysiologically, post-traumatic or exogenous osteomyelitis is a primary local

affection characterized by avascularity (Burri 1975, Popkirov 1971, Waldvogel et al 1971) The transition to a chronic stage begins in the first days after the injury because this type of osteomyelitis represents both an ischaemic and an infectious problem A sequestrum is frequently present initially Table 3 shows that the symptoms of post traumatic osteomyelitis could be diagnosed within 1 month of the injury in 60 per cent of the material

Sequestrectomies and saucerizations, eventually combined with removal of implants and renewed internal or external fixations were the chief methods of treatment used in our cases, but other methods such as bone transplantation and skin reconstruction have proved valuable in healing the infection (Table 5)

The surgical treatment is difficult time-consuming and full of disappointments because of recurrent flare-ups, fistulas and pathological fractures. The orthopaedic surgeon should try to plan a schedule of treatment for each individual case, this may eventually mean several interventions per patient Taking into consideration that about 100 operations were performed at the primary general surgical departments this means a mean total of four operations per patient

An integration of radical surgery and antibiotic therapy is essential in the management of most cases of post traumatic osteomyelitis (Rowling 1970) The group of 47 patients treated with surgery and lincomycin achieved a satisfactory result in 85 per cent and the difference between the results in pure *staphylococcal* infections and in mixed ones is significant The lincomycin sensitive organisms usually disappeared but the mixed infections continued in three patients and necessitated amputations

The three patients with four lincomycin resistant lesions also deserve a few comments Two patients with pure cultures of *staphylococci aurei* showed resistance at the first test and in the subsequent 6 and 9 cultures respectively and ultimately amputation was performed The last patient with two osteomyelitic foci with mixed infectio showed lincomycin sensitivity in the first t and subsequently several cultures show resistant *staphylococci aurei*

In our opinion the advantages of a clo irrigation-suction technique are that provides mechanical rinsing of the wound penetrates necrotic tissue not yet remo with a radical procedure and it prepare profuse purulent focus for an immediate later acceptance of a cancellous graft.

Such a perfusion with lincomycin was u in about half the cases, and was perhaps m successful in the various infected pseudarthroses in connection with rigid traskeletal fixation The irrigation was larg applied as described in the literat (Compere et al 1967, Dombrowski & D 1966 Michelinakis 1972 Taylor & Mauds 1970, Willenegger et al 1970) but technique must be carefully adapted to the dividual case The importance of inserting tubes through oblique cortical burr-holes good distance from the focus to avoid kink and blocking of the inlet and outlet drains emphasized Moreover, the efficiency of irrigation system with the overlapping t ends must be tested with 250 500 ml of solution during and after wound closure a frequently checked during the first 24 hou

From a therapeutic point of view it is fi of all of great importance to establish whet the osteomyelitic process is combined wit pseudarthrosis or not On admission, 44 cent of the infected fractures in this mate also revealed a pseudarthrosis which crea great therapeutic problems. In most cases bridging of a purulent pseudarthrosis w autologous cancellous bone grafts should postponed until the infection has subsided is safer to saucerize and remove sequestra and unstable metal implants combined w irrigation and renewal of rigid internal or traskeletal fixation as a first procedure and perform bone grafting as a secondary meas on a freshened pseudarthrotic bed in a qu period a few weeks later The analysis of series also supports the observation made others (Alho et al 1972 Macausland & Eat

...1963 McNeur 1970) that it is an advantage to maintain a rigid osteosynthesis even during an aggressive form of osteomyelitis until the fracture has clinically consolidated. The tendency to heal is determined as much by the consolidation of the fracture as by the reversal and restitution of the infectious process.

In a few cases the ischaemic component of the tibial osteomyelitis with pronounced cicatrization is undoubtedly so evident that skin grafting reconstructions are necessary to promote healing and prevent recurrence. It seems unsuccessful to perform split-skin grafting primarily upon saucerized cavities packed with cancellous bone. In this respect our experience corresponds with that of Burri (1975) who states that it is more profitable not to close the skin but to wait for spontaneous epithelialization or put split-skin grafts on the granulation tissue as a secondary measure.

A question which sooner or later always arises in this field of surgery concerns the magnitude of the saucerization because a radical bone excision inevitably means a skeletal weakness and the danger of a pathological fracture. In a given case a little more than half of the shaft might be removed to obtain an adequate blood circulation on all ... surfaces. Our series indicates that a pathological fracture is a complication that may lead to subsequent amputation. Autologous cancellous bone transplantation constitutes the best prophylactic measure.

The results in our series are encouraging although the amputation rate was 13 per cent. In the pre-antibiotic era the rate of amputation was over 50 per cent, while the rate today according to the literature varies between 2.2 and 15 per cent (Burri 1975). ... of our eight amputated patients with ... open and two closed tibial fractures ... primarily fixed with plates using the ...romedial approach.

The use of metal for internal fixation has ...led to an increased incidence of infection ... osteosynthesis provides stability and ... osteosynthesis material is covered by sufficient live tissue (McNe... 1971). Hagen (1969) repo... osteomyelitis among 129 n... leg and femur fractures (4.5 p... none (0 per cent) after osteos... corresponding fractures.

However, the increasing num... high velocity road traffic accidents with extensive soft tissue damage and comminuted tibial fragments require special consideration. The injury is already comprehensive and any additional approach to the medial surface of the tibia entails a potential risk of subsequent osteomyelitis (Bauer et al. 1962, Edwards 1965).

The lateral approach to the tibia for plate osteosynthesis seems to be a better choice from an infectious as well as a biomechanical point of view. If there is extensive damage to soft tissue both pretibially and laterally, the possibility still exists of using the little known posteromedial approach to the tibia which is seldom used. Lastly, a transfixation procedure with Hoffmann's apparatus may also be a very valuable form of treatment for these fractures with severe soft tissue damage (Olerud 1973).

In conclusion, it now often seems possible to heal bone infections of this type if the surgical procedure is sufficiently radical and combined with appropriate antibiotic therapy. In addition, in certain cases plastic reconstructive methods and extraskeletal fixation are necessary to avoid disappointments in this challenging field of orthopaedic surgery.

REFERENCES

Alho A., Koskinen E. V. S. & Malmberg H. (1972) Osteomyelitis in nonoperative and operative fracture treatment. A survey of 49 ... Clin. Orthop. 87, 123–133.

[illegible]

Burri C. (1975) [illegible] Hans Huber Publishers, Bern Stuttgart-Vienna.

Compere, F L, Metzger, W. I & Mitra, R N (1967) The treatment of pyogenic bone and joint infections by closed irrigation (circulation) with a non-toxic detergent and one or more antibiotics *J Bone Jt Surg* 49 A, 614–624

Dombrowski, E T & Dunn, A W (1966) Treatment of osteomyelitis by débridement and closed wound irrigation suction *Clin Orthop* 43, 215–231

Edwards, P (1965) Fractures of the shaft of the tibia 492 consecutive cases in adults Importance of soft tissue injury *Acta orthop scand*, Suppl 76

Hagen, R (1969) Osteomyelitis in a general surgical department *Acta orthop scand* 40, 673–674

Hagen, R (1971) Osteosynthesis of multiple open fractures. *Nord Med* 85, 383

Macausland, W R & Eaton, R G (1963) The management of sepsis following intramedullary fixation for fractures of the femur *J Bone Jt Surg* 45-A, 1643–1653

McNeur, J C (1970) The management of open skeletal trauma with particular reference to internal fixation *J Bone Jt Surg* 52 B, 54–60

Michelinakis, E (1972) Treatment of chronic osteomyelitis with the continuous irrigation-suction method *Acta orthop scand* 4 25–31

Olerud, S (1973) Treatment of fractures by th Vidal-Adrey method *Acta orthop scand* 4 516–531

Paus, B (1971) Chronic osteomyelitis. A report o fifty cases treated with lincomycin (Lincocin *Acta orthop scand* 42, 320–327

Popkirov, S (1971) *Die Behandlung d hämatogenen und der traumatische Osteomyelitis* V E B Verlag Volk un Gesundheit, Berlin

Rowling, D E. (1970) Further experience in th management of chronic osteomyelitis. *J Bon Jt Surg* 52-B, 302–307

Taylor, A R & Maudsley, R H (197 Instillation-suction technique in chronic os teomyelitis. *J Bone Jt Surg* 52 B 88–92

Waldvogel, F A, Medoff, G & Swartz, M N (1971) *Osteomyelitis Clinical features therapeutic considerations, and unusu aspects* Charles C Thomas, Springfield Illinois.

Willenegger, H., Ledermann, M, Wahl H G & Plaass, U (1970) Über das Wesen d Spuldrainage *Die posttraumatische Osteo myelitis*, ed Hierholzer, G & Rehn, J., p.79 Schattauer, Stuttgart New York.

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:HE PENETRATION OF CEFAZOLIN, :RYTHROMYCIN AND METHICILLIN NTO HUMAN BONE TISSUE

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The penetration of cefazolin, erythromycin and methicillin into normal bone was studied in 20 patients undergoing surgery for fracture in the trochanteric region of the femur The antibiotic concentrations were determined in serum, bone marrow and cancellous and cortical bone For all three antibiotics the bone marrow concentrations were of the same order of magnitude as the serum concentrations. In the eight patients receiving erythromycin, detectable concentrations were found in all the cancellous bone specimens (ranging from 1/7 to 1/2 of the serum concentration) and in three cortical bone specimens (ranging from 1/50 to 1/5 of the serum concentration) In the six patients receiving cefazolin a detectable concentration was found in only one cancellous bone sample In the six patients receiving methicillin, detectable concentrations were found only in the blood contaminated specimens of one cancellous and two cortical bone samples However, by the method used the recoveries of standard solutions of methicillin in cancellous and cortical bone were about 50 per cent and 15 per cent respectively

Key words antibiotic, bone tissue cefazolin erythromycin methicillin

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eral studies of antibiotic concentrations in one tissue have been performed, but the sults are difficult to compare and often conting (Beavis et al 1977, Smilack et al 976). This could be due to differences in the one type examined (Evaskus et al 1969, dlin et al 1977), whether there are disnctions made between bone marrow, ncellous and cortical bone (Hansen et al 975), variations in the amount of blood conmination of the bone specimens, and differences in the homogenization or extraction procedure, and the assay method used (Parsons 1976, Dornbusch et al 1977)

The present study was concerned with the measurement of cefazolin, erythromycin and methicillin concentrations in bone tissue from the distal femur of patients with fractures the trochanteric region, using a homoge tion procedure already described for antibiotics (Hansen et al 1975, Niel 1976)

Compere F L, Metzger, W I & Mitra R N (1967) The treatment of pyogenic bone and joint infections by closed irrigation (circulation) with a non toxic detergent and one or more antibiotics. *J Bone Jt Surg* 49 A 614–624

Dombrowski, E T & Dunn A W (1966) Treatment of osteomyelitis by debridement and closed wound irrigation suction *Clin Orthop* 43, 215–231

Edwards, P (1965) Fractures of the shaft of the tibia 492 consecutive cases in adults. Importance of soft tissue injury *Acta orthop scand*, Suppl 76

Hagen R (1969) Osteomyelitis in a general surgical department *Acta orthop scand* 40, 673–674

Hagen, R (1971) Osteosynthesis of multiple open fractures. *Nord Med* 85, 383

Macausland, W R & Eaton, R G (1963) The management of sepsis following intramedullary fixation for fractures of the femur *J Bone Jt Surg* 45-A, 1643–1653

McNeur, J C (1970) The management of open skeletal trauma with particular reference to internal fixation *J Bone Jt Surg* 52 B 54–60

Michelinakis, F (1972) Treatment of chronic osteomyelitis with the continuous irrigation-suction method. *Acta orthop scand* 4 25–31

Olerud S (1973) Treatment of fractures by t Vidal Adrey method *Acta orthop scand* 4 516–531

Paus, B (1971) Chronic osteomyelitis. A report [illegible] fifty cases treated with lincomycin (Lincocin [illegible] *Acta orthop scand* 42, 320–327

Popkirov, S (1971) *Die Behandlung d hämatogenen und der traumatisch[illegible] Osteomyelitis* V E B Verlag Volk u Gesundheit Berlin.

Rowling, D E. (1970) Further experience in th management of chronic osteomyelitis. *J Bo Jt Surg* 52 B 302–307

Taylor, A R & Maudsley, R H (197[illegible] Instillation-suction technique in chronic o[illegible] teomyelitis. *J Bone Jt Surg* 52 B 88–92

Waldvogel F A Medoff G & Swartz, M [illegible] (1971) *Osteomyelitis Clinical features therapeutic considerations, and unusua aspects* Charles C Thomas, Springfielc Illinois.

Willenegger, H., Ledermann M, Wahl H G & Plaass, U (1970) Über das Wesen de Spuldrainage *Die posttraumatische Osteo myelitis* ed Hierholzer, G & Rehn, J, p [illegible] Schattauer Stuttgart-New York.

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RESULTS

The concentrations of cefazolin, erythromycin and methicillin in bone marrow, cancellous and cortical bone, as well as the calculated serum values are shown in Table 1 Furthermore the dose of antibiotic and the time interval between the last dose (or the end of infusion) and the taking of bone specimens are shown

It is seen that the bone marrow concentrations were of the same order of magnitude as the serum concentrations for all three antibiotics

All the bone specimens from the six patients receiving cefazolin were blood contaminated, even so there was a detectable concentration in only one cancellous bone sample (12 μg/g)

In the eight patients receiving erythromycin, the concentrations in the cancellous bone samples ranged from 0 6 to 5 5 μg/g which was 1/7 to 1/2 of the corresponding serum values In cortical bone there were detectable concentrations in the two samples with visible blood contamination which gave 0 51 μg/g and 1 8 μg/g, but a detectable concentration of 0 18 μg/g was found in only one of the non-contaminated samples However, by the method used the recovery of standard erythromycin solutions in cortical bone was only about 35 per cent (see material and methods)

In the six patients receiving methicillin

Table 1 The concentration of cefazolin erythromycin and methicillin in serum (calculated) and bone tissue

Antibiotic	Pt no	Dose (g)	Time after last dose or the end of infusion (min)	Antibiotic concentrations: Serum (μg/ml)	Bone marrow (μg/ml)	Cancellous bone (μg/g)	Cortical bone (a) (μg/g)
Cefazolin	1	1	45	81	43	12+	ND+
	2	1	325	6 8	10	ND+	
	3	1	175	44	44	ND+	
	4	1 × 4	120	90	94	ND	
	5	1 × 3	265	31	34	ND+	
	6	1 × 3	180	27	35	ND	
Erythromycin	7	0 5	90	2 1	2 1	0 6+	ND
	8	0 6	45	7 8	5 7	2 3+	0 5+
	9	1	65	9 8	8 7	4 6	1 8+
	10	1	15	11	NT	5 5	NT
	11	1	95	7 6	6 8	1 8	ND
	12	0 9	40	NT	12	2 3	0 18
	13	1	145	11	11	3 4	ND
	14	0 6	85	7 8	NT	1 2	ND
Methicillin	15	1	75	29	6 2	NT	2 9+
	16	1	70	21	17	3 0	2 5
	17	1	75	30	22	ND	
	18	1	70	15	10	ND	
	19	1	60	37	19	ND	
	20	1	80	22	13	ND	

+ Visible blood contamination ND Not a detectable concentration NT Not tested

(a) Measurements of the concentration in cortical bone specimens were performed only when the corresponding cancellous bone samples showed detectable concentration

MATERIAL AND METHODS

Twenty patients, 12 females and 8 males, were studied Their ages ranged from 48 to 92 years, with a mean of 75 years. All patients had a unilateral per- or subtrochanteric fracture of the femur, and they all underwent osteosynthesis *ad modum* Ender, an intramedullary fixation using three or more nails. (Briefly, the nails are introduced just above the medial femoral condyle and passed up the shaft, across the fracture and into the neck and caput of the femur) None of the patients had received antimicrobial medication for at least 7 days prior to this investigation Serum creatinine was normal in all patients.

Bone specimens were taken from the medial supracondylic region of the femur as soon as the bone was exposed for the osteosynthesis. In the first nine patients cortical bone was taken with a Lexcelles cutting nippers, whereas a curette was used for the cancellous bone It was, however, impossible by this method to avoid visible blood contamination of the specimens. Because of this the subsequent bone specimens were taken with a cylindrical drill with an internal diameter of 10 mm, by means of which it was possible to obtain a cylinder consisting of both cancellous and cortical bone, without visible blood contamination Immediately after the samples were taken, cancellous and cortical bone were separated and stored at —20°C until assayed Bone marrow was obtained by aspiration through a metal cannula introduced through the biopsy hole and placed 5–10 cm proximally in the marrow canal The marrow material was centrifuged and the supernatant (except the fat fraction) was used for the measurements

After weighing the bone specimens were mogenized according to the method of Hansen t al. (1975) to a particle size of 0 3–3 2 micrometers Cancellous bone was homogenized for 1 hour and cortical for 4 hours Bone materials were dispersed in pooled human serum For technical reasons serum four times the volume of the specimens was added to the cancellous bone prior to the homogenization procedure as described by Hansen et al whereas serum twice the volume of the specimens was added to the cortical bone after homogenization

All the antibiotics were given intravenously prior to surgery Cefazolin (Kefzol[a]) was given in doses of 1 g Erythromycin was administered as a continuous infusion of a solution containing 1 g erythromycin-lactobionate (Abbott) in 1000 ml 0 9 per cent sodium chloride The average infusion rate was 650 mg per hour The infusion was stopped prior to the operation, and the total amount given ranged from 500 mg to 1000 mg

Methicillin (Lucopenin[a]) was given as a single 1 dose The time interval from the last dose give (or the end of infusion) until the bone and marro specimens were taken ranged from 15 to 3 minutes with a mean of 106 minutes.

Two samples of venous blood were draw between 5–90 minutes before, and betwe 25–120 minutes after the bone specimens we taken The antibiotic concentrations in seru were determined either on the same day, or t serum was stored at —20°C until assayed. Th antibiotic concentration in serum at the time t bone specimens were taken was calculate according to the formula $=y_0e$ kt where y [illegible]

[illegible]

strain of *Bacillus subtilis* was used as the te organism for all three antibiotics. Difco Antibiot Medium No 4 was used for cefazolin a methicillin and Antibiotic Medium No 5 f erythromycin

Standard solutions of antibiotics were prepare in pooled human serum for the following reason When standard solutions of cefazolin an erythromycin were prepared by adding know amounts to cancellous bone followed by 1 hou homogenization, standard curves identical to th curves obtained in pooled human serum wer found However, when methicillin was added t cancellous bone and homogenized for 1 hour th recovery was only 32 to 74 per cent measure against serum standards. When the thre antibiotics were added to cortical bone an homogenized for 4 hours the recovery was only to 56 per cent for cefazolin 19 to 50 per cent fo erythromycin, and 4 to 30 per cent for methicilli against serum standards It is seen that th recovery for each antibiotic varied considerabl from experiment to experiment and by usin these homogenates as standard solutions n accurate standard curves would be obtained.

Because of the low recovery after the 4 hou homogenization procedure measurements o antibiotic concentrations in cortical bon specimens were performed only when the cor responding cancellous bone samples showe detectable concentrations

Minimum serum and marrow concentration detectable were 0 5 μg/ml for cefazolin 0 06 μg m for erythromycin and 0 3 μg/ml for methicillin The corresponding concentrations in cancellou bone homogenates were 2 5 μg/g 0 3 μg/g and 1 μg/g and in cortical bone homogenates 0 15 μg/g 0 18 μg/g and 0 9 μg/g respectively (In thre specimens less than the standard 200 mg bon material was available and the minima measurable concentrations were higher)

of erythromycin were found in bone tissue. Cefazolin and methicillin showed sufficient marrow concentrations, but detectable concentrations in bone samples were only found infrequently, which as regards cefazolin was in contrast to the high bone concentrations reported by other authors.

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REFERENCES

Evans, J. P., Parsons, R. L., Davis, J. A., Paddock, G. M. & Laurence, M. (1977) Plasma, hip capsule, bone and drain fluid concentrations of cefazolin, flucloxacillin and ampicillin during total hip replacement. *10th Int. Congr. Chemoth.* [illegible]

Cunha, B. [illegible] Nights [illegible] penetration characteristics of cefazolin, cephalothin and cephradin into bone in patients undergoing total hip replacement. *J Bone Jt Surg* 59-A, 856–859.

Dornbusch, K., Carlström, A., Hugo, H. & Lidström, A. (1977) Antibacterial activity of clindamycin and lincomycin in human bone. *J Antimicrob Chemother* 3, 153–160.

Evaskus, D. S., Laskin, D. M. & [illegible] (1969) Penetration of lincomycin, [illegible] tetracycline into serum and [illegible] *exp Biol. Med* 130, 89–91.

Grady, J. E. & Stern, K. F. (19[illegible]) lincomycin into bone. *Antim[illegible]* *Chemother.* 201–205.

Hansen, I., Nielsen, M. L. & Nielsen, J. B. (19[illegible]) A new method for homogenization of bone exemplified by measurement of trimethoprim in human bone tissue. *Acta pharmacol (Kbh)* 37, 33–42.

Nielsen, M. L., Hansen, I. & Nielsen, J. B. (1976) The penetration of lincomycin into normal human bone. *Acta orthop scand* 47, 267–270.

Parsons, R. L. (1976) Antibiotics in bone. *J Antimicrob Chemother* 2, 228–231.

Pitkin, D. H., Sachs, C., Zajac, I. & Actor, P. (1977) Distribution of sodium cefazolin in serum, muscle, bone marrow and bone of normal rabbits. *Antimicrob Agents Chemother* 11, 760–762.

Rosdahl, N. T., Vejlsgaard, V., Rosdahl, N. & Vejlsgaard, R. (1969) A micromethod for determination of antibiotics in serum. *Dan Med Bull* 16, 133–139.

Schurman, D. J., Johnson, B. L., Finerman, G. & Amstutz, H. C. (1975) Antibiotic bone penetration. *Clin Orthop* 3, 142–146.

Smilack, J. D., Flittie, W. H. & Williams, T. W. (1976) Bone concentrations of antimicrobial agents after parenteral administration. *Antimicrob Agents Chemother* 9, 169–171.

Wick, W. E. & Preston, D. A. (1972) Biological properties of three 3-heterocyclic-thiomethyl cephalosporin antibiotics. *Antimicrob Agents Chemother* 1, 221–234.

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METHYLMETHACRYLATE HYPERSENSITIVITY IN A PATIENT WITH CEMENTED ENDOPROSTHESIS

A Case Report

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A case of methylmethacrylate monomer hypersensitivity in a 76-ye… patient with a cemented endoprosthesis is reported The accuracy o… method for preoperative testing of a patient's sensitivity is discussed.

Key words allergic reaction, hip arthroplasty methylmethacrylate

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After reports of several cases of sudden death during endoprosthesis fixation with methylmethacrylate cement (MMC) (Kepes et al 1972, Monteny et al 1975) as well as various cases of loosening of the prosthesis or of skin eruptions due to an allergic reaction (Bouffioux 1959, Laugier & Foussereau 1966, … Ashman & Miller 1976, Oleffe & Wilmet 1972) attention has been drawn to the possible hypersensitivity of these patients to the different components, i e, metal and MMC, introduced into the organism during operation

Benson et al (1975), Elves et al (1975), Evans et al (1974) and Nater et al (1976) reported a high incidence of hypersensitivity to nickel, cobalt and vanadium in patients with a hip prosthesis In the present study patients with a hip arthroplasty were investigated for sensitivity to methylmethacrylate monomer (MMM) by patch tests and a case of hypersensitivity to MMM is reported

CASE REPORT

A 76-year-old woman underwent a left … replacement During implantation of … endoprosthesis and the acrylic cement into … femoral shaft the blood pressure decr… characteristically The postoperative course … uneventful The patient's history revealed tha… had undergone a Moore arthroplasty … transcervical fracture of the right hip 6 years … viously She wore a double dental prost… without trouble Patch tests were perform… weeks postoperatively The 5 per cent M… patch test was negative whereas the 20 an… per cent MMM patch tests were strongly pos… Biopsy of the last test was interpreted a… allergic response following the main line… Achten & Oleffe (1966)

METHODS

during operation and reduced to posit…

ted. After the first results 20 and 40 per cent MMM (in olive oil) tests were added to the test tray

Forty-two patients were investigated (36 women and 6 men, average age 68 9 years) All patients underwent a hip arthroplasty using MMC (McKee-Farrar and Moore) The case histories revealed earlier hip arthroplasty in nine patients, dental prostheses in 31 and both hip and dental prostheses in seven

The patch tests were performed on the arm as the patients were lying on their back To prevent poss'ble evaporation phenomena the patches were covered with a MMC cup or an aluminum patch (Silverpatch Van Der Bend) The patch tests were applied for a period of 48 hours and read after 48 and 96 hours.

DISCUSSION

Hypersensitivity to methylmethacrylate has been reported to occur in dentists (Fisher ...) patients with dental prostheses (Crissey 1965 Dechaume & Brunel 1948, ...ez et al 1970, Jedrzejewski & ...lewicz Stysiak 1970), manicurists (Canizares 1956, Fisher et al 1957) and a laboratory technician (Moody 1941) but the incidence of methylmethacrylate skin sensitivity in the general population remains unknown. Nyquist (1958) noted 90 per cent positive reactions in a student nurse population with a 5 per cent concentration dispersed in olive oil or paraffin. On the contrary, Nater et al (1976) with the same concentration in ...e did not obtain a single positive reaction in patients with total hip replacement.

These authors agree upon the role of MMM as an allergen After polymerization of MMM the polymer may be considered as inert provided the reaction of polymerization is complete and no monomer is left

In patients with a cemented endoprosthesis sensitization to MMM seems to be very rare (Bouffioux 1959, Nater et al 1976) A certain amount of MMM is pushed into the injured blood vessels when the prosthesis and MMC are packed into the femoral shaft (...y 1969, Pahuja et al 1974) This may produce a sensitization reaction as the elimination of the monomer via the respiratory system is reduced (Derks & D'Hollander 1977) The negative reactions with the polymer reduced in powder confirm previous works (Oettel 1963) Our study is also in accordance with Nater's results (1976) as no positive reaction was observed with a 5 per cent concentration of MMM

In view of the conflicting results further investigations of methylmethacrylate sensitivity are relevant We believe a 20 per cent concentration of MMM is more adequate than a 5 per cent concentration Chloroform is used as a solvent As a 40 per cent concentration is usually employed to test chloroform allergy (Fisher 1975) the latter is not involved in the reaction

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REFERENCES

Achten G & Oleffe J (1966) Tests épicutanés et dermatoses professionnelles. Etude histologique *Bull Soc franç Derm Syph* **73**, 49–52

Benson M K.D Goodwin P G & Brostoff J (1975) Metal sensitivity in patients with joint replacement arthroplasties. *Brit med J* **4**, 374–375

Bouffioux, J (1959) Allergie à l acrylique Manifestations cutanées et générales. *Arch belges Derm* **15**, 336–337

Canizares, O (1956) Contact dermatitis due to the acrylic materials used in artificial nails. *Arch Derm* **74**, 141–143

Crissey J T (1965) Stomatitis, dermatitis and denture materials. *Arch Derm* **92**, 45 48

Dechaume M & Brunel M (1948) Les manifestations buccales d intolérance aux résines méthacryliques. *Rev Stomat* **49**, 700–709

Derks, C.M & D'Hollander A A. (1977) Some aspects of pulmonary excretion of

Methylmethacrylate monomer (MMM) in dogs *J surg Res* **22**, 9–15

Elves, M W, Wilson, J N, Scales, J T & Kemp H B S (1975) Incidence of metal sensitivity in patients with total joint replacements *Brit med J* **4**, 376–378

Evans, E M, Freeman, M A R, Miller, A J & Vernon-Roberts, B (1974) Metal sensitivity as a cause of bone necrosis and loosening of the prothesis in total joint replacement *J Bone Jt Surg* **56-B**, 626–642.

Fisher, A A (1954) Allergic sensitization of the skin and oral mucosa to acrylic denture materials. *J Amer med Ass* **156**, 3, 238–242.

Fisher, A A, Franks, A & Glick, H (1957) Allergic sensitization of the skin and nails to acrylic plastic nails. *J Allergy* **28**, 84–88

Fisher, A A (1975) *Contact dermatitis* (2nd Edition) Lea & Febiger, Philadelphia

Foussereau, J & Benezra, C (1970) *Les eczemas allergiques professionnels* Masson & Co, Paris

Fregert, S (1974) *Manual of contact dermatitis* Munksgaard, Copenhagen

Huriez, C, Martin, P, Larere, L, Donazzan M & Carlier, C (1970) Intolérances de la muqueuse buccale aux matériaux prothétiques *Bull Dermat* **77**, 424–427

Homsy, C A (1969) Prosthesis seating compounds of rapid cure acrylic polymer Joint workship on total hip replacement and skeletal attachment National Academy of Science, American Academy of Orthopaedic Surgeons.

Jedrzejewski T & Danilewicz-Stysiak, Z (1970) Rôle de la résine méthacrylique dans l'etiologie des stomatopathies prothétiques *Rev Stomat* **71**, 289–293

Kepes E R Underwood P S & Becsey, L (1972) Intraoperative death associated with acrylic bone cement *J Amer med Ass* **222**, 576–577

Laugier, P & Foussereau J (1966) Les dermite allergiques à distance provoquees par l matériel d'ostéosynthèse *Gaz méd Fr* 2, IX 3409–3418

Malten, K E. & Zielhuis, R L. (1964) *Industria toxicology and dermatology in the productio and processing of plastics* Elsevier Publish n Company

Monteny, E, Jaspar N & Dubois Primo J (1975 Rôle possible du méthacrylate de méthyle dan les accidents cardio-vasculaires observés e chirurgie orthopedique *Anesth Analg Réanim* **32**, 119–124

Moody, W L (1941) Severe reaction from acryli liquid *Dent Dig* **47**, 305

Munro-Ashman, D & Miller A J (1976 Rejection of metal to metal prosthesis and sk sensitivity to cobalt *Contact Dermatitis* 2 65–67

Nater, J P, Brian R G, Deutman, R & Mulder Th (1976) The development of meta hypersensitivity in patients with metal to plastic hip arthroplasties. *Contact Dermatiti* **2**, 259–261

Nyquist G (1958) Sensitivity to methy metacrylate *Trans R Sch Dent Stockh Umea* **1**, 36–51

Oettel, H (1963) Biologische Probleme bei de [illegible]

hip arthroplasty Van Gorcum & Co, Asse The Netherlands.

Oleffe, J & Wilmet J (1972) Eczema généralis et vis d ostéosynthèse *Arch belges Derm.* 28 275–278

Pahuja, K, Lowe, H & Chand K (1974) Bloo methyl methacrylate levels in patients having prosthetic joint replacement *Acta orthop scand* **45**, 737–741

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MPUTATION AFTER DEVELOPMENT OF COLLATERAL CIRCULATION

n Arteriographic Study in Rabbits

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The vascular changes in the amputation stump after amputation on an extremity which is vascularized by collaterals were studied by arteriography in adult rabbits

Amputation on the crus immediately after ligature of the femoral artery caused a retardation in the development of collaterals and a protracted vasoconstriction in the amputation stump Osseous plugging of the medullary cavity in the amputation stump counteracted the vasoconstriction and the development of collaterals was improved When amputation on the crus was performed 3 6 days after ligature of the femoral artery immediate function of the collaterals and a rapid dilatation of the arteries in the below knee amputation stump were seen and 3–4 weeks postoperatively arteriovenous shunts developed in the stump Amputation 7–10 weeks after ligature of the artery involved a more pronounced shunt development in the amputation stump

After amputation on the femur only slight differences were observed in the development of collaterals and the vascularization in the amputation stump compared with findings after amputation on the crus

Key words amputation arteriovenous shunt collateral circulation intracardial arteriography vascular spasm

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he vascular changes occurring after amputa on may influence the healing process in the nputation stump especially if the amputan is performed on an extremity with duced arterial supply In earlier ex rimental investigations arteriography has own that amputation initially induces sospasm (Erikson & Olerud 1966) and condarily causes arteriovenous shunts to velop in the stump (Hansen Leth & Karle 78). When amputation is performed on an tremity supplied by collaterals formed ecause of occlusion of the femoral artery the uscle blood flow to the stump will depend on the time interval between the occlusion and the amputation (Hansen Leth 1978)

The aim of this investigation was to elucidate the arteriographic changes in the stump after amputation on extremities supplied by collaterals Arteriography was performed after intracardial injection of contrast as in an earlier investigation (Hansen Leth & Karle 1978)

MATERIALS AND M[illegible]

The studies were [illegible] weighing 3–4 kg [illegible]

Table 1 Examples of repeated arteriographic investigations on the same rabbit

Operations	Time of arteriography			
	Rabbit N 62		Rabbit N 70	
Ligature of the femoral artery	Preoperative 1 hour after ligature 1 week after ligature			
Ligature of the femoral artery + amp on crus	10 weeks	+ 1 hour	½ week	+ 1 day
	— —	+ 2 weeks	— —	+ 1 week
	— —	+ 4 —	— —	+ 3 —
	— —	+ 10 —	— —	+ 5 —
	— —	+ 13 —		
Ligature of the femoral artery + amp on femur			10 weeks	+ 1 hour
			— —	+ 1 week
			— —	+ 6 weeks
			— —	+ 8 —

proximal part of the left femoral artery, and the amputation stumps were in all cases closed by myoplasty In nine rabbits amputation proximally on the left crus was performed immediately after the ligature – in three of these myoplasty was combined with osseous plugging of the marrow cavity In five animals amputation on the crus was carried out 3–6 days and in a further five animals 7–10 weeks after the ligature Finally, in two animals previously amputated on the crus – amputation on the femur was performed 1 week and 10 weeks after the ligature Two animals were not amputated at all

All the operations were performed under Nembutal anaesthesia The femoral artery was double-ligated with silk and the stump was closed silk knots in the muscles and nylon in the skin e marrow cavity was plugged with cortex tained from the removed bone

Arteriography was carried out as previously described (Hansen-Leth & Karle 1978). Under Nembutal anaesthesia a lumbar needle (90 × 0 9 mm) was inserted through the skin at the tip of the xiphoid process and thrust into the heart The needle was kept open with heparin-saline solution and a bolus of 6 cm³ 76 per cent Urographin was injected manually for a period of 1 5 seconds Six pictures were taken immediately thereafter (1 exposure every 2 seconds) This procedure clearly portrayed the arterial and venous phase and the transit-time through the arteries and the appearance of the venous phase could be determined

The degree of change in arterial diameter was measured on subtraction films at corresponding levels by the use of a magnifying glass and a scale permitting readings with a precision of 01 m The magnification factor was so small that could be ignored (measured with a lead strp ruler placed across the pelvic area of the rabb

A total of 57 arteriographs were performed, t preoperative, seven after arterial ligature and after amputation from 1 hour to 4 mon postoperatively Two animals were arteriograph 8 times (Table 1) one 4 times, five 3 times, se twice and eight once

RESULTS

When arteriography was performed ir mediately after ligature of the femoral arter function of the collaterals from the circumfl femoral arteries and contrast filling of t distal part of the femoral artery were see but no filling of the crural vessels. From 1 10 weeks after ligature of the femoral arter arteriography showed a moderate increase the prominence of the collaterals and on a slight amount of contrast in the cru arteries (Figure 1)

If amputation on the crus was perform immediately after the arterial occlusion only few collaterals were seen in the amputated l in the first 4 weeks after the operation ar the contrast filling in the stump vessels w minimal up to 6 weeks (Figure 2) When weeks had passed a dilatation of t



Figure 1 (a) Ten weeks after ligature of the left femoral artery Note the moderately prominent collaterals and almost no contrast filling of the crural arteries (b) Postmortem angiography performed on the same rabbit through a catheter placed in the aorta Rabbit N69

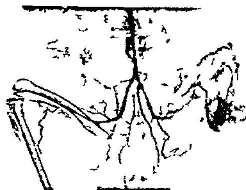


Figure 3 Two weeks after simultaneous ligature of the femoral artery and amputation on the crus combined with plugging of the medullary cavity (N₃₃)

supplying arteries and slight filling of the veins was observed (Table 2)

However if amputation was combined with plugging of the medullary cavity dilatation of the collaterals and the arteries in the stump was seen 1 week postoperatively (Figure 3)

After a time interval of from 3 to 6 days between ligature of the artery and amputation, arteriography showed an immediate contrast filling of the collaterals dilatation of the arteries in the stump was seen 2 days later (Figures 4 5) Four weeks postoperatively there was filling of the superficial and deep veins in the stump and the superficial veins in the contralateral extremity

In experiments with 7 to 10 weeks interval between ligature and amputation arteriography immediately after amputation showed little contrast filling of the collaterals and the vessels in the stump (Figure 6) Two weeks later more collaterals were seen (Figure 7) and there was simultaneous vein filling on both sides.

Table 2 illustrates that the flow rate in the arteries was almost constant (4–6 seconds) and independent of the time interval between artery ligature and amputation whereas vein filling increased 2–3 weeks postoperatively and was most noticeable when a long time interval (7–10 weeks) was introduced between artery occlusion and amputation

Contrast filling of the veins occurred simultaneously on both sides but on the contralateral extremity only the superficial veins were seen, and they disappeared when a tourniquet was placed on the distal part of

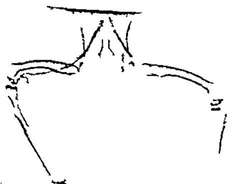


Figure 2 Ten weeks after ligature of the femoral artery and amputation on the crus performed simultaneously (N_{44})



Figure 4 (a) Five days after ligature of the femoral artery (b) One hour after subsequent amputation (c) Two days after the amputation (N_{14})

Table 2 Transit time Rate of contrast filling in the vessels in the operated leg (One sign means a single picture = 2 seconds)

TRANSIT-TIME

OPERATION	1 HOUR	1/2 WEEK	1 WEEK	2-3 WEEKS	4 5 WEEKS	6 10 WEEKS	>10 WE
LIGATURA ART FEMORALIS	x x	x x x	x x x x x	x x x		x x	x x x
SIMULTANEOUS LIG AND AMP CRURIS	x x	x x x x	x x	x x x x x x	x x	x x △△△△ x x ooo	x x △ x x △△
SIMULTANEOUS LIG AND AMP • PLUGGING		x x △△△	x x △△	x x oo x x △△△	x x x x		
INTERVAL 3-6 DAYS	x x x x x	x x x x x x	x x △△ x x x x	x x △△ x x △△△△	x x ●●● x x oooo	x x △△△ x x ooo	x x x ●●● x x oooo x x △△△
INTERVAL 7 10 WEEKS	x x x x x x	x x x x		x x △△△ x x x ooo x x x ●●	x x x ●●● x x ●●●●	x x ●●●●●	x x ooo x x x △△
LIG AND AMP FEMORIS	x x x		x x	x △△	x x	x x	

x ARTERY OCCURRENCE
△ VEIN SLIGHT OCCURRENCE
o VEIN MODERATE OCCURRENCE
● VEIN MARKED OCCURRENCE

the crus, indicating that the vein filling was caused by arteriovenous shunts distally in the extremity In the amputated extremity contrast filling of the superficial as well as the deep veins was observed, the superficial veins were especially noticeable after a long time interval between artery occlusion and amputation

The dilatation of the suppling arteries is illustrated by the diameter of the aorta (Figure 8) The degree of dilatation with 3–6 days interval between artery occlusion and amputation was greater than after 7–10 weeks interval, and remained unchanged the investigation period, while the diam of the aorta increased after the longer t interval

The secondary dilatation of the suppl arteries and the increased occurrence superficial veins in the stump, especially a a long time interval between artery occlus and amputation, could be explained by formation of arteriovenous shunts in t amputation stump

If amputation on the femur was perform 1 and 10 weeks after artery occlus



gure 5 Amputation on the crus and later on the femur performed on the same rabbit (a) Three days ter ligature and 1 hour after amputation (b) Three days after ligature and 5 weeks after amputation) Ten weeks after ligature and 1 hour after amputation on the femur (d) 10 days later (N_{10})

) contrast filling of the distal part of the moral artery was seen, the circumflex teries were dilated but the collaterals in the ump were only slightly so and no vein filling curred (Figure 5) However dilatation of the teries and rapid filling of the veins were seen the contralateral extremity

ISCUSSION

ing intracardial arteriography it is possible perform repeated investigations on the me animal and in this way to follow the velopment of collaterals after ligature of the moral artery and the vascular changes lowing subsequent amputation

This study has demonstrated immediate function of collaterals after ligature of the femoral artery Similarly Schoop & Jahn (1961) showed immediate contrast filling of preexisting "primary" collaterals after ligature of the femoral artery on dogs while "secondary' collaterals developed in the course of the following weeks In clinical investigations Shepherd (1950) and Dornhorst & Sharpey Schafer (1951) showed that the resistance in the collateral vessels diminished already 1 minute after acute arterial occlusion

In the present study there was no contrast filling of the crural arteries before 1 week after the occlusion despite the development of collaterals This is in accordance with the findings of Barnes & Trueta (1942) and Jaya (1958) who found that ligature of the femoral



ure 6 (a) Seven weeks after ligature (b) Amputation performed at this time and the arteriography 1 ır later (c) Three days later (N_{11})



Figure 7 The amputation was performed 10 weeks after ligature and the arteriography 4 weeks later (N_{11})

artery induced a vasospasm of the peripheral arteries. Measurement of the muscle blood flow (Hansen-Leth 1978) has shown that after ligature of the femoral artery there is an immediate reduction in the blood flow to the crus.

In this study, amputation performed immediately *after arterial occlusion counteracted* the function of collaterals and induced a protracted vasoconstriction in the peripheral arteries in the amputated extremity Measurement of the blood flow in muscles (Hansen-Leth 1978) has shown that the flow in th *stump is decreased during the first week aft* simultaneous ligature of the femoral artery an amputation on the crus. This is in contrast t *crus amputation on rabbits with intact circula*tion where an increase in blood flow was 1 day after operation (Hansen-Leth 1976)

When *amputation* is done on an extremit with intact circulation an initial vasospasm will always be the result (Erikson & O 1966, Hansen-Leth & Karle 1978). However if the amputation is performed 3–6 days afte ligature of the femoral artery, an immediat dilatation of the supplying arteries and fillin of the collaterals to the stump are seen. In accordance with this, determination of muscl blood flow (Hansen-Leth 1978) has shown a immediate increase in the *blood flow to th* stump, when amputation on the crus is performed 3 days after ligature of the femora artery *The reason why amputation on a* extremity supplied by collaterals does n provoke an initial vasospasm is not clear

MM 45 40 35 30 25 20

1 HOUR 5 10 15 20 30 40 50 70 90 100 DAYS

x OCCLUSION ARTERIA FEMORALIS
● 3 6 DAYS BETWEEN OCCLUSION AND AMPUTATION
Δ SIMULTANEOUS OCCLUSION AND AMPUTATION
O 7 10 WEEKS BETWEEN OCCLUSION AND AMPUTATION

Figure 8 The diameter of the aorta A secondary dilatation is observed 3–4 weeks after amputation especially after a long interval between occlusion and amputation

Erikson & Olerud (1966) suggested that the vasospasm after amputation could be caused by an increased sympathetic tone From clinical investigations it is known that collaterals have a low sympathetic tone (Nielsen et al 1973) A decreased sensitivity to the sympathetic impulses could be the cause of the immediate function of collaterals after amputation

After an extended time interval between arterial occlusion and amputation a similar natural vasodilatation and collateral function was not seen But secondary arterial dilatation was observed after 3–4 weeks simultaneously with the occurrence of contrast filling of the superficial veins This might be due to the development of arteriovenous shunts in the stump, and these findings can explain the diminished muscle blood flow in the amputation stump seen when amputation was performed 10 weeks after arterial occlusion (Hansen-Leth 1978)

The occurrence of superficial veins can be due to arteriovenous shunts, whereas the contrast filling of deep veins means an improvement in the venous return from the stump (Loon 1960) In a previous investigation (Hansen Leth & Karle 1978) the deep veins from the stump were only seen when amputation was combined with osseous plugging of the medullary cavity Similarly, the present investigation has shown that plugging of the medullary cavity improved the vascularization in the stump In accordance with this, determination of muscle blood flow (Hansen-Leth 1976) has shown that plugging of the marrow cavity induces a more rapid and greater blood flow in the stump

Following amputation on the femur only a slight filling via the collaterals to the femoral stump was seen and there was no refilling of the femoral artery After amputation on the femur the femoral artery must be considered an end artery, which is obliterated at the level where it joins with the circumflex femoral arteries The vascularization of the amputation stump takes place only through small terminal branches, the fall in blood pressure through these is marked (Learmonth 1950) and the capillary blood flow in the stump will be diminished In accordance with this, determination of muscle blood flow has shown no increase in the flow in the stump after amputation on the femur (Hansen-Leth 1977)

REFERENCES

Barnes, J M & Trueta, J (1942) Arterial spasm An experimental study *Brit J Surg* **30,** 74–79

Dornhorst, A C & Sharpey-Schafer, E P (1951) Collateral resistance in limbs with arterial obstruction Spontaneous changes and effects of sympathectomy *Clin Sci* **10,** 371–378

Erikson U & Olerud S (1966) Healing of amputation stumps with special reference to vascularity and bone *Acta orthop scand* **37,** 20–28

Hansen Leth C (1976) Muscle blood flow after amputation with special reference to the influence of osseous plugging of the medullary cavity *Acta orthop scand* **47,** 613–618

Hansen Leth, C (1977) Muscle blood flow after amputation with special reference to the influence of the amputation level *Acta orthop scand* **48,** 10–14

Hansen Leth, C & Karle A (1978) Intracardial arteriographic study on vascular changes in amputated rabbits *Acta orthop scand* (In press)

Hansen Leth, C (1978) Collateral circulation and amputation *Int Orthop* (In press)

Jaya Y (1958) Contralateral vasoconstriction in the hind limb of the rat and rabbit *Clin Sci* **17,** 55–61

Learmonth, J (1950) Collateral circulation natural and artificial *Surg Gynec Obstet* **90,** 385–392

Loon, H E (1960) Biological and biomechanical principles in amputation surgery *Prosthetics International,* pp 41–58 Committee on Prostheses, Braces and Technical Aids – International Society for the Welfare of Cripples, Copenhagen

Nie [illegible]

Schoop W & Jahn U (1961) Entwicklungsstadien arterieller Kollateralen und ihre begriffliche Definition *Z Kreis Forsch* 50, 249–254

Shepherd J T (1950) The effect of acute occulsion of the femoral artery on the blood supply to the calf of the leg before and after release of sympathetic vasomotor tone *Clin Sci* 9, 355–365

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PNEUMATIC TOURNIQUET AND LIMB BLOOD FLOW

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The response of limb circulation to tourniquet ischaemia in the hind limb of the rabbit was studied. Muscle blood flow was evaluated by means of a local isotope technique using Xe^{133} as the tracer and the changes occurring after tourniquet ischaemia of 60–180 minutes duration were investigated. The results obtained suggest that even when the tourniquet time is extended to 3 hours, no blood flow occurs in the limb distal to the tourniquet when the cuff is inflated to 300 mmHg. In all animals a hyperaemic reaction was noticed after releasing the tourniquet and a peak reactive hyperaemia was registered 1 minute after the return of circulation. The magnitude of the reactive hyperaemia was independent of the length of tourniquet time. The hyperaemia was regularly of short duration and peak flow values were reached in 1 minute with the flow returning to normal or subnormal values after 5 minutes. Phlebography studies in 12 rabbits after 120–240 minute tourniquet blockade showed only one thrombosis in a deep popliteal vein after the 240-minute tourniquet time.

Key words: pneumatic tourniquet, limb blood flow, ischaemia, thrombosis

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Pneumatic tourniquet is a commonly used technique for the exsanguination of a limb and obtaining a bloodless field for surgery of the extremities (Esmarch 1873, Cushing 1904). Some authors suggest that despite correct application of the tourniquet blood may flow into the distal part of the limb by the way of the medullary canal (Spira et al. 1965, Furlow 1971), the amount varying from 1 to 26 per cent of the flow to the unoperated limb. Klenerman & Crawley (1977) reported however, in an experimental study, that the circulation was reduced to less than 1 per cent of that of the control limb.

Reddening of the skin of the limb after removal of the tourniquet as a sign of reactive hyperaemia was observed by Bier already in 1897. Even a short occlusion of the arterial blood flow of less than 5 minutes produces reactive hyperaemia (Myhre 1975). However, there is little accurate data on the blood flow to the limb after releasing the tourniquet. Several methods have been used to study reactive hyperaemia, venous occlusion plethysmography being one of the most common. However, this technique may impede the arterial blood flow and, furthermore, the measurement must be made at intervals (Dahn 1965). Estimation of venous outflow by drop recording technique and electromagnetic flowmetry have been successfully used to measure rapid changes in blood flow after brief arterial occlusion (Thulesius 1962, Myhre 1975). Recently, the local isotope clearance technique using Xe^{133} as the tracer has proved to be a convenient method to evaluate muscle blood flow (Lindbjerg 1966, Siggaard-Andersen & Bonde-Petersen 1967). In these experiments the circulatory occlusion was extended to 60 minutes. A reactive hyperaemia was always noted after the return of circulation.

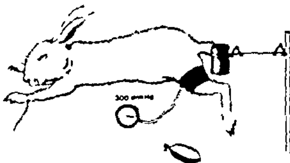


Figure 1 Schematic illustration of the model used in the experiments The scintillation detector for the Xe^{133} wash out registration was placed 5 cm above the limb

Postoperative venous thrombosis has been considered as a rare complication after pneumatic tourniquet (Geens et al 1969 Potter et al 1972) However, other authors have reported, in phlebographic studies that the incidence of venous thrombosis after pneumatic tourniquet varies from 10 to 60 per cent (Cohen et al 1973, Kroese & Stiris 1976) Evidence has been presented that the thrombosis appears already during the first postoperative hour (Flanc et al 1968 Negus et al 1968)

The purpose of this study was to clarify the circulatory situation in the limb during the use of the pneumatic tourniquet to evaluate the blood flow after releasing the tourniquet and to find out if postoperative thrombosis appears as a complication

MATERIAL AND METHODS

Thirty-one rabbits of both sexes weight 2 7–3 4 kg were used in this study Anaesthesia was induced with intravenous sodium pentobarbitone and maintained by continuous ether inhalation

The left hind limb was exsanguinated with an Esmarch rubber bandage and tourniquet blockade was applied by means of a 6 cm broad Riva Rocci type cuff around the upper part of the leg the cuff being inflated to 300 mmHg (Figure 1) The response of different periods of tourniquet blockade on the extremity blood flow was investigated Six rabbits were subjected to 60 minutes of tourniquet ischaemia another six to 120 minutes, the remaining six being subjected to 180 minutes of tourniquet ischaemia

The hind limb blood flow was measured by th Xenon[133] wash out technique. Into the middle pa of the anterior tibialis muscle 0 2 ml of a solutio of Xe^{133} was injected in sterile isotonic sal... mCi/ml Rotop[2], Isocommerz GmbH, Berli Buch DDR) with a thin needle (No. 16 OD (mm) The injection was performed for 10 secon the needle being withdrawn 20 seconds af finishing the injection. The disappearance rate the isotope from the limb was followed by mea of a scintillation detector with a thallium activa NaI-crystal which was placed 5 cm above limb The scintillation detector was coupled t Wallac[3] ratemeter (Wallac Ltd Turku, Finla The output from the ratemeter was recorded o logarithmic Servogor[5] chart recorder (Go Electro GmbH Vienna Austria) On the assu tion of diffusion equilibrium of Xe^{133} betw tissue and blood calculation of the muscle bl flow was made according to the Fick princ (Lindbjerg 1966)

Phlebography of the hind leg after pneu tourniquet was performed on a further 12 rab Four rabbits had a 120-minute tourn ischaemia and in four rabbits the duratio blockade was 180 and 240 minutes, respecti Radiographic examination was performed w 30 minutes of the release of the tourniquet inject the contrast medium, the skin in the l leg was incised and a catheter was inserted i distal part of the great saphenous vein An was taken also with phlebography tourniqu visualize the deep veins of the limb

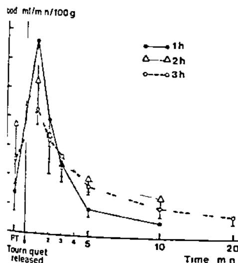
In one rabbit an angiogram of the common artery and its distal ramifications was perfo After laparatomy a catheter was intro through the left renal artery into the aort angiogram was taken during the tour occlusion and 30 minutes after the release tourniquet

RESULTS

The average of 18 determinations o normal blood flow baseline in the hind was 24 ± 8 1 ml/min/100 g muscle (mea s e m)

During the tourniquet blockade no de of Xe^{133} activity could be demonstrat dicating that no wash out occurred. observation was made in all the a under investigation and the tourniquet did not affect the results

When the tourniquet blockade was re



...re 2 *Reactive hyperaemia registered after ...sing the tourniquet Note the peak of the ...d flow 1 minute after onset of the circulation ... magnitude of the hyperaemia was not ...ficantly dependent on the tourniquet time ...in 5 to 10 minutes the flow had turned to ...al or subnormal values PT=pretourniquet ...e*

... 60 minutes, the Xe^{133} wash out ...ased 1 minute after return of the circula... to 68.8 ± 12.4 ml/min/100 g ($P < 0.05$) ...r this, the wash out decreased sharply 5 minutes after releasing the blockade the ... out was lower than the normal baseline ...± 4.2 ml/min/100 g) (Figure 2)

... the 120-minute group the Xe^{133} wash increased 1 minute after tourniquet ...se to 52.1 ± 8.5 ml/min/100 g Five ...tes after the release the value for wash ...as 19.2 ± 2.1 ml/min/100 g

... the 180-minute group 1 minute after ...se of the tourniquet blockade the wash ...ad increased to 42.1 ± 8.7 ml/min/100 g ...ad declined 5 minutes after the release ...$.5 \pm 2.0$ ml/min/100g

...lebography revealed one venous throm... in a deep popliteal vein after 4 hours ...urniquet blockade (Figure 3b) In all the animals phlebography revealed a patent ...s flow In all rabbits the phlebo...y was technically successful, but throm... could not be demonstrated (Figure 3a)

In the angiogram a clear occlusion of the arterial blood flow was seen just above the inflated tourniquet cuff

The control angiogram 30 minutes after the onset of circulation showed a normal angiogram in the tourniquet limb

DISCUSSION

In 1949, Kety suggested that tissue blood flow could be measured by means of the disappearance of locally injected radioactive isotopes Applying this principle, a radioactive isotope of the inert gas Xenon (Xe^{133}) has been used for experimental and clinical measurements (Lassen et al 1964, Lindbjerg 1966) This isotope has proved to have theoretical advantages over other isotope clearance methods (Lassen et al 1964)

The results obtained in the present investigation, using the Xe^{133} clearance method, suggest that even when the tourniquet time is extended to 3 hours, no blood flow occurs in the limb distal to the tourniquet cuff This result correlates with those obtained by Klenerman & Crawley (1977) They reported a blood flow to the occluded limb of less than 1 per cent, when compared with the control limb Their study was performed using the Na^{22} clearance method. It seems obvious that during these experimental conditions the circulation via the medullary canal is almost totally occluded and that the limb is virtually isolated from the circulation

Hyperaemia following brief arterial occlusion has been recognized previously (Thulesius 1962, Lindbjerg 1966 Siggaard-Andersen & Bonde-Petersen 1967, Myhre 1975) However, tourniquet ischaemia is in

tourniquet blockade after 1-, 2- and 3-hour periods of ischaemia In the present work the peak of reactive hyperaemia was in all animals registered 1 minute after releasing the tourniquet blockade Lindbjerg (1966)



Figure 3 (a) Normal phlebography
(b) Thrombosis in a deep popliteal vein following 4 hours of tourniquet occlusion

reports in human experiments that up to a period of 5 minutes of occlusion the amount of hyperaemia increased in accordance with the duration of the ischaemia but that further prolongation of the ischaemia did not cause a further increase in hyperaemia In Lindbjerg's work the maximal blood flow in the human tibialis anterior muscle was measured after 5 minutes ischaemia combined with simultaneous exercise and the peak flow of 70 8 ml/min/100 g was often maintained for more than 1 minute In our study the maximal peak flow was registered after 60 minutes of tourniquet ischaemia and was comparable with the maximal muscle blood flow reported by Lindbjerg

Shepherd (1950) and Hillestad (1963) have reported a peak blood flow of 40–50 ml/min/100 g in human calf muscles after brief strenuous exercise These values resemble the flow in the rabbit tib anterior muscle during hyperaemia follow release after 120 and 180 minutes of tour quet blockade Thulesius (1962) suggests t blockade of the extremity blood flow has effect on the limb circulation comparable w strenuous exercise since both result in a co siderable reduction of collateral resistance

Several mechanisms have been propos for the reactive hyperaemia such accumulation of vasodilatator substanc (Lewis & Grant 1925) and reduced vascul tone due to a fall in transmural press distal to the occlusion (Bayliss 1902, Folkow 1964) Local oxygen deficiency has also bee held responsible for reactive hyperaem (Crawford et al. 1959) Myhre (1975) suggest that the metabolites which are accumulated during circulatory arrest enter circulation and maintain increased blood flow at least after

of prolonged occlusions The cause of seems to be complex and can uted to the influence of a single only

The blood flow in the tibialis anterior 5–10 minutes after release of the is lower than the pretourniquet value, but still within the range of values obtained under normal conditions 1950, Hillestad 1963, Lindbjerg

mental phlebographic studies to the incidence of thrombosis after ischaemia have not previously performed Our results with only one is in 12 rabbits do not justify con- of clinical consequences, but suggest, however, that further experimental work should be done in this field

On the basis of the present investigation, the results may be summarized as follows

A pneumatic tourniquet inflated to 300 caused a total blockade of the circula- in a hind limb of a rabbit,

The magnitude of reactive hyperaemia releasing the tourniquet did not significantly depend on the tourniquet time,

Blood flow peak values were reached 1 minute after the return of circulation, with re-establishment of normal or subnormal values occurring within 5–10 minutes, and

Postoperative venous thrombosis was found in only one animal after 240 minutes of tourniquet time.

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REFERENCES

Bayliss, W (1902) On the local reactions of the arterial wall to changes of internal pressure *J Physiol* **28**, 220–231

Bier, A. (1897) Die Entstehung des Collateral-Kreislaufs. Theil I Die arterielle Collateral-Kreislauf *Arch Path. Anat Physiol* **147**, 256–293

Cohen, S., Ehrlich, G & Kaufman, M (1973) Thrombophlebitis following knee surgery *J Bone Jt Surg* **42 A**, 945–950

Crawford, D, Fairchild, H & Guyton A (1959) Oxygen lack as a possible cause of reactive hyperaemia. *Amer J Physiol.* **197**, 613–616

Cushing H (1904) Pneumatic tourniquet with especial reference to their use in craniotomies. *Medical News* **84**, 577–583

Dahn, I (1965) On clinical use of venous occlusion plethysmography of calf *Acta chir scand* **130**, 42–60

[illegible] Blutleere bei [illegible] Vortrage in [illegible] Klinikern

[illegible] (1968) The detection of venous thrombosis of the legs using ^{125}I labelled fibrinogen. *Brit J Surg* **55**, 742–747

Folkow, B (1964) Description of the myogenic hypothesis. *Circulat Res* **14–15**, Suppl. 1 1279–1287

Furlow, L (1971) Cause and prevention of tourniquet ooze *Surg Gynec Obstet* **132**, 1069–1072.

Geens, S, Clayton, M., Leidholt, J., Smyth, C. & Bartholomew, B (1969) Synovectomy and debridement of the knee in rheumatoid arthritis and osteoarthritis. Clinical and roentgenological study of thirty-one cases. *J Bone Jt Surg* **51 A**, 626–642.

Hillestad, L (1963) The peripheral blood flow in intermittent claudication. *Acta med scand* **174**, 671–685

Kety, S (1949) Measurement of regional circulation by the local clearance of radioactive sodium *Amer Heart J* **38**, 321–328

Klenerman L & Crawley J (1977) Limb blood flow in the presence of a tourniquet *Acta orthop scand* **48**, 291–295

Kroese A. & Stiris G (1976) The risk of deep vein thrombosis after operations on a bloodless lower limb A venographic study *Injury* **7**, 271–273

Lassen, N Lindbjerg I & Munck O (1964) Measurement of blood flow through skeletal muscle by intramuscular injection of Xe^{133} *Lancet* **1**, 686–689

Lewis, T & Grant R (1925) Observations upon reactive hyperaemia in man *Heart* **12**, 73–120

Lindbjerg I (1966) Leg muscle blood flow measured with ^{133}Xenon after ischaemia periods and muscular exercise performed during ischaemia *Clin Sci* **30**, 399–408

Myhre, H (1975) Reactive hyperaemia in the hind limbs of rabbits. The effect of changes in occlusion time *Acta chir scand* **141**, 259–265

Negus, D, Pinto, D, Le Quesne, L. & Brown, N (1968) [125]J-labelled fibrinogen in the deep vein thrombosis and its correlation with phlebography *Brit J Surg* **55**, 835–839

Potter, T., Weinfeld, M & Thomas, W (1972) Arthroplasty of the knee in rheumatoid arthritis and osteoarthritis. A follow-up study after implantation of the McKeever and McIntosh prostheses. *J Bone Jt Surg* **54-A**, 1–24

Shepherd, J (1950) The blood flow through the calf after exercise in subjects with arteriosclerosis and claudication. *Clin. Sci* 9, 49–58

[illegible] (1967) [illegible] and [illegible] on the calf in normal subjects. *Scand. J clin Lab Invest* **19**, 106–112.

Spira, E., Karznelson, A., Czerniak, P & Mikolajkow, A. (1965) Osseous blood circulation in the lower limb *Israel J med Sci* 1, 573–57[illegible]

Thulesius O (1962) Haemodynamic studies on experimental obstruction of the femoral artery in the cat *Acta physiol scand*, Suppl 199

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OSTEOSARCOMA

A Multifactorial Clinical and Histopathological Study with Special Regard to Therapy and Survival

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A multifactorial analysis was performed on all 153 unequivocal cases of genuine osteosarcoma recorded in the Swedish Cancer Registry for the years 1958 through 1968 Cases of so-called parosteal osteosarcoma, soft-tissue osteosarcoma and osteosarcoma secondary to Paget's disease of bone were not included The osteosarcomas were subclassified as follows osteoblastic (69 per cent), chondroblastic (19 per cent) and fibroblastic (12 per cent) The overall 5-year survival rate was 22 per cent, 55 per cent for those who had undergone amputation above the joint proximal to the involved skeletal part, 22 per cent for those amputated on the involved skeletal part, 11 per cent for those treated with local extirpation of the tumor, and 1 per cent in cases in which the lesion was not radically removed Tumors of the femur, humerus and scapula were as malignant as axial tumors The former carried a 5-year survival rate of 13 per cent, regardless of whether the patients had been treated with exarticulation or amputation on the involved skeletal part Patients with axial tumors showed a 5 year survival rate of 15 per cent These survival data suggest that proximal amputation alone might suffice for lesions situated distally to the knee and elbow joints, while tumors in the humerus and femur should be treated with amputation combined with multicytostatic treatment or immunotherapy and axial tumors with local resection and multicytostatic or immunologic treatment

Key words osteosarcoma therapy, histopathological study

Accepted 24 v 78

Despite several reports in the medical literature of large series of genuine osteosarcoma, there is still some controversy as to the overall prognosis In earlier reports, the estimated 5-year survival rate ranged from about 5 to over 30 per cent (Simmons 1939, Jaffe & Selin 1951), while in later series it ranges from 10 to 20 per cent (McKenna et al 1964, Dahlin & Coventry 1967) However, the patient populations have been influenced by selection to a varying degree (McKenna et al 1964) The results might also have been influenced by improvements in diagnostic and treatment efficiency over the years.

The present investigation represents a combined clinical and histopathological analysis of osteosarcomas collected from those recorded in the Swedish Cancer Registry during the 11-year period from 1958 through 1968 The overall 5-year survival rate was determined, and also the survival in

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relation to various factors such as tumor site and kind of treatment Primary attention was thus paid to factors which have been considered to influence the survival rate, such as histopathological type of tumor, site and size of tumor, rapidity of tumor growth and soft-tissue involvement, diagnostic measures, presence or absence of fracture, age and sex, and mode of therapy This information may provide a basis for the indications for primary ablative surgery, either alone or in combination with adjunctive chemotherapy or immunotherapy, and also for evaluation of the results which may be achieved with new therapies for osteosarcoma, e g chemotherapeutics such as methotrexate or adriamycin (Editorial 1974 Cortes et al 1974 Pratt et al. 1974, Sutow et al. 1974, Campbell et al 1975) immunotherapeutics such as intravenous transfer of sensitized lymphocytes (Southam et al 1973, Editorial 1974, Neff & Enneking 1975) or interferon administration (Nilsonne et al 1975)

MATERIAL AND METHODS

Since 1958 all cases of clearly malignant and possibly malignant tumors diagnosed in Sweden have been *reported* to the Cancer Registry by a very efficient system (Larsson 1971) of *double* reporting throughout the country from clinicians on one hand and pathologists and/or cytologists *on the other hand* The reliability of the data was discussed in a report from the Swedish National Board of Health and Welfare 1974 Two hundred and forty two patients were reported with a diagnosis of osteosarcoma during the years 1958 through 1968

The histopathological re-examination was carried out by one of the authors (L B) The *original slides* were re-examined and new sections were prepared and stained *with hematoxylin* and eosin van Gieson s stain periodic acid Schiff phosphotungstic acid hematoxylin and Laidlaw's silver impregnation Only those cases were accepted for further study *in which we could* prove a definite diagnosis of genuine osteosarcoma and in which *complete* clinical records *and biopsy* material were available to allow a multifactorial analysis Cases were thus excluded in which the diagnosis of osteosarcoma had been made primarily but could not be finally proved because of a lack of adequate histopathological material for thorough re-examination. *This means that the* number of patients accepted for the present analysis was smaller than the total number of recorded cases used in preceding incidence and *geographical studies* (Larsson & Lorentzon 1974a and b) The present series of unequivocal osteosarcoma cases thus had to be selected to enable an analysis as complete and representative as possible without limitation of the significance of the study (Lockshin & Higgins 1968).

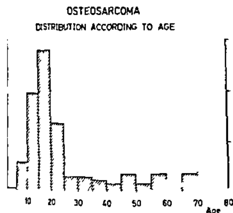
The possible influence of various factors, such as tumor localization and type of treatment, upon the prognosis, was subjected to statistical analysis using a chi square test When testing the possible simultaneous influence upon the prognosis of various factors such as the type of diagnostic procedure used a multiple regression analysis was performed (Angsmark 1969 Cramer 1954). All hypotheses were tested at the 1 per cent level of significance

RESULTS

Histopathological study

The histopathological diagnosis was osteosarcoma in all 242 cases recorded in the Cancer Registry but owing to the described criteria for our re-examination the present series consisted of only 153 proven genuine osteosarcomas A total of 23 cases represented either parosteal or extraosseous osteosarcomas or were secondary to Paget's disease of bone These cases were not included Thirty cases could not be fully proven to represent genuine osteosarcoma from the available material, and a few cases with unrelated malignancies had wrongly been registered as osteosarcoma These cases had lesions with central locations predominantly In 26 cases sufficient specimens and clinical records could not be obtained for a complete analysis, and six cases were excluded because their initial symptoms appeared the year before the time period covered by our study

Histopathologically the genuine osteosarcomas were subclassified as predominantly osteoblastic in 69 per cent of the cases, as chondroblastic in 19 per cent and as



;ure 1 Distribution of primary osteosarcoma :rding to age

roblastic in 12 per cent. This subclassifica- n was found to have no prognostic value, r did assessment of the degree of malig- ncy according to Broder's grading (Jaffe 58 Price 1961) have any prognostic gnificance

;e and sex

he age distribution of the genuine osteo- rcomas is shown in Figure 1 One peak was tained for the adolescent ages, two-thirds the neoplasms occurring in persons below l years of age An even distribution of the mors was found for the adult ages A milar age distribution was found for males nd females, apart from the fact that the peak cidence occurred at a mean age of 12 years girls and 16 years in boys, as previously ported (Larsson & Lorentzon 1974b) The dolescent incidence peak was caused by mors localized to the long bones of the wer limbs. The genuine osteosarcomas howed a predilection for males, giving the ollowing ratios for males to females for all ges together 1 47 to 1, in the ages below wenty-three 1 72 to 1 and in the ages above wenty three 1 11 to 1 Age was found not to nfluence the prognosis in the present series. Females had a slightly better prognosis than males, the 5-year-survival rates were 23 and 11 per cent, respectively

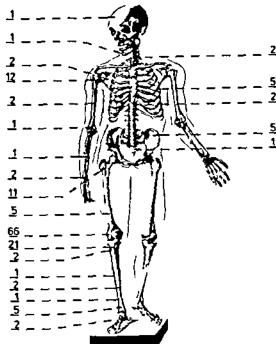


Figure 2 Skeletal distribution of primary osteosarcoma

Tumor location, and clinical and roentgeno-logical findings

The skeletal distribution of the genuine osteo- sarcomas is shown in Figure 2 Forty-three per cent affected the lower portion of the femur, 14 per cent the upper part of the tibia, and 7 per cent each the upper metaphyseal region of the femur and humerus No patient initially had more than one tumor

Twenty-four per cent of the neoplasms had a peripheral localization, i e distal to the knee and elbow joints (site 1), 65 per cent were located within the femur, humerus and scapula (site 2), and 11 per cent within the pelvis, spine, sacrum, ribs, mandibula and skull (site 3)

The most frequent symptom on admission was local pain noted in 91 per cent of the patients Local swelling was present in 81 per cent, limitation of motion of the adjacent joint in 45 per cent, pathological fracture in 14 per cent, a general feeling of sickness in 10

per cent, and neurological symptoms in 7 per cent of the patients

The most characteristic roentgenological appearance of the lesions was an expanded, osteolytic destruction of the affected bone, with areas of calcification often with visible bony structures, and periosteal new bone formation The majority of the cases presented with advanced lesions showing destruction of cortical bone and a relatively high frequency of pathological fractures (see above). Periosteal bone formation with spiculae and Codman's triangles was a prominent feature The neoplasms affected roentgenologically the metaphysis of a long bone in 61 per cent of the cases, the diaphysis in 7 per cent, the metaphyseal-diaphyseal border in 21 per cent, and a flat bone in 11 per cent of the patients.

Gross appearance

Some of the tumors were soft with areas of necrosis and cyst formation, while others were firm with chondromatous or ossified areas and central sclerosis.

The tumor size was estimated on roentgenograms and in some cases also on gross examination of the removed specimen Tumors larger than 10 cm in diameter were found in 44 per cent of the patients, tumors 5–10 cm in diameter were also found in 44 per cent, tumors 2–5 cm in 11 per cent and tumors smaller than 2 cm in 1 per cent of the cases. The peripheral lesions, i.e., those situated distally to the knee and elbow joints (site 1) were somewhat smaller (Table 1) than those in the femur, humerus and scapula (site 2) and the axial ones (site 3).

Table 1 The percentage distribution of genuine osteosarcoma according to tumor size on admission and primary localization

Tumor diameter in cm	Site 1	Site 2	Site 3
<2	2.7	0	5 9
2–5	21 6	8 2	5 9
5–10	51 4	42 3	35 3
>10	24 3	49 5	52 9
	100 0	100 0	100 0

Site 1 = radius, ulna, tibia, fibula and foot skeleton.
Site 2 = humerus, scapula and femur
Site 3 = rib, mandible, skull, spine sacrum and pelvis.

Soft-tissue involvement and joint penetration was determined roentgenographically at surgery, and at examination of the removed specimen Involvement of the surrounding soft tissues by the tumor had occurred in [illegible] per cent of the cases and penetration into the adjacent joint cavity in 12 per cent of the patients

Duration of symptoms before admission and "doctor's delay"

Thirty-nine per cent of the patients had experienced symptoms for less than 1 month before admission, 23 per cent complained of symptoms with 1 to 2 months duration and 26 per cent with 2 to 6 months duration.

The time which elapsed between the first contact with the physician and the institution of treatment ("doctor's delay") was less than 1 month in 50 per cent of the cases, 1 to 2 months in 20 per cent and 2 to 4 months in 16 per cent of the patients. No difference was found between the different tumor sites as to the time elapsed from the occurrence of symptoms until the institution of treatment.

Treatment

Local resection of the lesion was performed in seven patients (5 per cent) as shown in Table 2, local resection with inlay of bone graft in six (4 per cent) amputation on the skeletal part harboring the lesion in 39 ([illegible] per cent), amputation through a proximally situated skeletal part in 26 (17 per cent) amputation by exarticulation of the proximal joint in 25 (16 per cent) hemipelvectomy in two (1 per cent) and forequarter amputation in four patients (3 per cent) The neoplasm was not macroscopically removed in [illegible] patients (29 per cent)

...e 2 The distribution of the patients with genuine osteosarcoma according to treatment primary tumor localization and survival

... of treatment	Site 1	Site 2	Site 3	Survival
...l resection	3	1	3	See Figure 5
... + bone grafting	1	3	2	
...ation on the involved skeletal part	0	38	0	See Figures 5 and 6
+ extirpation of lymph nodes	0	1	0	2 months
...utation on the proximal skeletal part	25	0	0	See Figures 5 and 6
+ extirpation of lymph nodes	1	0	0	8 months
...rticulation	2	23	0	See Figure 6
...quarter amputation	0	4	0	4 7, 9 and 151 months
...ctomy	0	2	0	11 and 18 months
...macroscopically removed	5	27	12	See Figure 5
	37	99	17	

Chemotherapy was instituted primarily in ... per cent of the patients and palliatively in ...tients with pulmonary metastases in 14 per ...nt. Combined chemotherapy and radiation ...atment was given in 1 per cent of the ...tients

Treatment according to Cade (1947), i e ...mary high-dose radiation treatment ...lowed by amputation 6 months later in ...tients without pulmonary metastases, was ...rformed in 18 per cent of the patients ...diation treatment alone was given in 22 ...r cent of the cases, almost all of these were ...ually planned to receive a complete Cade ...atment but succumbed with pulmonary ...tastases before ablative surgery could be ...dertaken In 12 per cent of the patients ...iation treatment was given post-...ratively

...ognosis in relation to tumor localization ...d treatment

...e overall survival rate for all genuine os...sarcoma patients differed significantly ...m that obtained for patients grouped with ...pect to tumor localization and kind of ...atment The overall 2-year survival rate ...s 31 per cent, and the overall 5-year ...vival rate was 22 per cent (Figure 3)

...atients with a peripheral localization of ... neoplasm (Figure 4, site 1) had a significantly better prognosis than those with more centrifugal tumors (sites 2 and 3) The 5-year survival rate for patients with site 1 tumors, i e lesions located distally to the knee and elbow joints, was 47 per cent, that for patients with site 2 tumors i e lesions in the

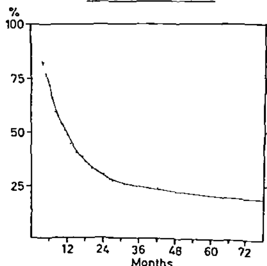


Figure 3 Rate of survival of all 153 patients with histopathologically verified primary osteosarcoma recorded in the Swedish Cancer Registry for the years 1958 through 1968

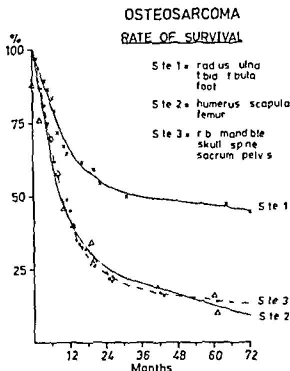


Figure 4 Rate of survival of the osteosarcoma patients according to tumor site Patients with peripheral tumors (site 1) had a significantly ($P < 0.001$) *better survival rate than those with tumors of the femur, humerus and scapula (site 2) or axial tumors (site 3) The symbols indicate survival percentage at each point of analysis (the same as in Figures 6 and 7)*

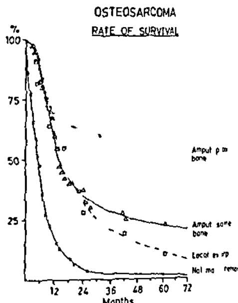
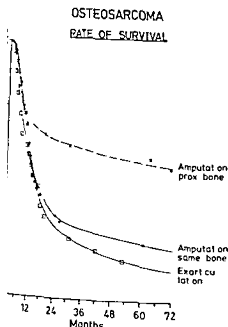


Figure 5 Rate of survival of the osteosar... patients according to the extent of surgi... treatment performed Patients amputated abo... the joint to the involved skeletal part h... significantly ($P < 0.001$) *better survival rate th... those treated with amputation on the invol... skeletal part or local extirpation of the bone ... those who did not have their tum... macroscopically removed*

humerus, scapula and femur 13 per cent, and that for site 3 tumors, i e lesions in the ribs, mandible, skull, spine, sacrum and pelvis, 15 per cent While the better prognosis of site 1 tumors in relation to that of site 2 and site 3 tumors was statistically highly significant ($P < 0.001$) no significant difference was found between site 2 and site 3 tumors The 2-year survival rates for patients with the three different tumor localizations were 54, 25 and 24 per cent, respectively Although the tumors of site 1 were somewhat smaller than those of sites 2 and 3 the different prognoses were apparently associated with the type of treatment used and not so much with differences in tumor aggressiveness

When the prognosis was related to the kind of treatment instituted (Table 2 and Figures 5 and 6), amputation on the skeletal p... proximal to that harboring the neoplasm w... associated with a significantly bett... prognosis than other kinds of treatme... (Figure 5) Thus, patients who had underg... amputation above the joint proximal to t... involved skeletal part showed a 5 y... survival rate of 55 per cent (site 1 tumor... those amputated on the involved skeletal p... 22 per cent (site 2 tumors) those treated w... local extirpation of the tumor 11 per ce... and those in whom the lesion was ... macroscopically removed 1 per cent The ... year survival rates were 62 35, 32 and 5 ... cent, respectively Thus, ablative surgery ... also local extirpation of the tumor ... associated with a definitely better progn... than non-operative treatment The be... prognosis for patients treated with h... amputation (site 1 tumors) than for th... amputated on the involved skeletal part (...



: 6 Rate of survival of the osteosarcoma ts in relation to the level of the ablative y performed Patients amputated above the proximal to the involved skeletal part had cantly (P < 0 001) better survival rates than treated with amputation on the involved il part or exarticulation Patients who had 'one hip exarticulation did not have a better 'ns than those amputated on the involved il part

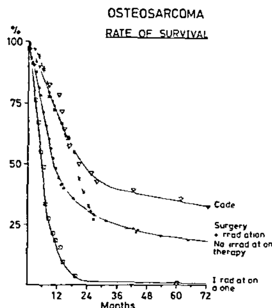


Figure 7 Rate of survival of the osteosarcoma patients [illegible] Patients [illegible] treated [illegible] treated with irradiation alone were scheduled to undergo treatment according to Cade but succumbed with pulmonary metastases before ablative surgery could be undertaken Patients who had received a complete Cade treatment had survival rates comparable to those treated with primary ablative surgery alone

ors) was statistically highly significant 001). Patients who had undergone ation on the involved skeletal part had ificantly ($P < 0.001$) better prognosis hose who had received non-operative ent.

prognosis in relation to the level of e surgery performed is shown in 6 While patients who had undergone amputation (site 1 tumors) showed a antly better prognosis than those with amputation on the involved l part (site 2 tumors) exarticulated s (with site 2 tumors predominantly) ound to have a bad prognosis The 5- urvival rates for these categories of s were 55, 22 and 14 per cent, ively

Patients who had received radiation treatment alone showed a very poor prognosis (Figure 7), the 5-year survival rate was less than 1 per cent Some patients in this group had very advanced tumors already at the time of diagnosis This group also included cases who initially were scheduled to receive treatment according to Cade, but pulmonary metastases occurred before surgery could be instituted Patients who had undergone a complete Cade treatment showed a 5-year survival rate of 35 per cent The corresponding figure for those primarily treated with ablative surgery was 21 per cent The combined group of patients consisting of those who had undergone a complete Cade treatment and those who had received radiation treatment alone showed a

significantly lower 5-year survival rate than those who primarily were treated surgically.

Chemotherapy with cyclophosphamide was given as an adjuvant after amputation in a limited number of patients. Although the data did not demonstrate a significant effect of this treatment upon the prognosis, a slight tendency towards an improved prognosis was found. Ten patients received local perfusion of the involved extremity with very high doses of cyclophosphamide prior to amputation. Three of these patients survived for more than 5 years.

Influence of diagnostic procedure upon prognosis

The various diagnostic procedures used in the present series were found not to exert any statistically significant effect upon the prognosis. Using multiple regression analyses it was not possible to demonstrate any significant influence, upon the prognosis of the different diagnostic procedures used, e.g. frozen section and surgery primarily, biopsy and surgery secondarily in a bloodless field, biopsy and surgery secondarily without a bloodless field, and surgery primarily without biopsy.

DISCUSSION

The 5-year survival rate of 22 per cent in all genuine osteosarcomas of the present series corresponds very well with the 23 per cent survival rate in the Mayo Clinic series (Dahlin & Coventry 1967), but is lower than the 28 per cent reported for the series from South-West England (Price 1962) and the 34 per cent recorded in an early American series (Coley & Pool 1940). However, the 5-year survival rate in our series is definitely higher than the 11 per cent recorded at the Memorial Centre for Cancer in New York between 1925 and 1955 as reported by McKenna and his colleagues (1966) who excluded patients dying after 5 years follow-up, and the 15 per cent survival rate record at the Massachusetts General Hospital fro 1920 to 1962 (Weinfeld & Dudley 1962).

Patients with small tumors had somewhat better prognosis than those w large ones. However, the majority of t patients had large tumors on admission or 12 per cent presented with lesions less th 5 cm in diameter. Involvement of the s rounding soft tissues by the tumor had marked effect upon the prognosis. Patie with soft-tissue involvement had a 5-ye survival rate of only 18 per cent compar with 39 per cent in patients who had no so tissue involvement. However, the latter gro of patients constituted only 18 per cent a the former 82 per cent, indicating that t vast majority of the patients had advanc neoplasms on admission, although 61 per ce had experienced symptoms for less than months. Nevertheless, the prognosis m improve if diagnosis can be made at an earl stage of the disease. The 5-year survival was found to be better in with a long a short symptoms

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Readily accessible osteosarcomas suitable for surgical treatment, e g peripheral tumors, are generally considered to carry a better prognosis than non-excisable, e g axial tumors (Lockshin & Higgins 1968) The skeletal distribution of osteosarcoma is similar in different reports and that of the present series does not deviate markedly Thus, 43 per cent of the tumors were located in the distal femur and 14 per cent in the proximal tibia The peripheral tumors situated distally to the joints of the knees and elbows carried a significantly better prognosis than those situated in femur, humerus and scapula the 5 year survival rates being 47 and 13 per cent, respectively On the other hand the corresponding figure of 15 per cent obtained for the axial tumors did not differ significantly from that of the tumors situated within the femur and humerus Although surgically accessible, the latter osteosarcomas thus carried as poor a prognosis as did the axial tumors The two categories of lesions showed no difference with regard to parameters such as tumor size and duration of symptoms on admission

The 47 per cent 5-year survival in osteosarcomas situated distally to the joints of the knees and elbows is better than the corresponding figure of 36 per cent reported for the Mayo Clinic series which showed a 10-year survival rate of 27 per cent (Dahlin & Coventry 1967) The peripheral tumors of the present series also showed a better prognosis than that reported earlier for tumors of the area (Coley & Pool 1940, Dahlin & Coventry 1967, McKenna et al 1966, Price 1966, Sweetnam, Knowelden & Dudley 1962) On the other hand, the 5-year survival rate of 13 per cent for the osteosarcomas of the femur and humerus in the present series is less than the 16 to 21 per cent rate reported in the studies cited above For the axial tumors, the survival rate of 15 per cent is somewhat higher than the 5 to 13 per cent rate recorded in the earlier series. Apparently, the neoplasms of the femur and humerus of the present series were more malignant than earlier considered

It is evident from the data of the present study that primary amputation above the joint proximal to the involved skeletal part is the best treatment for tumors situated distally to the joints of the knees and elbows, i e site 1 tumors, giving a 5-year survival rate of 55 per cent This unexpectedly high survival rate makes the rationale of using combined primary chemotherapy with drugs like adriamycin, methotrexate, cyclophosphamide, vincristine and 1-phenylalanine mustard questionable for patients with these peripheral lesions, when the serious toxic effects of these agents are taken into consideration In addition, chemotherapy does not seem to prevent the late occurrence of metastases For tumors of the femur and humerus (site 2) and for axial tumors (site 3), primary multi-cytostatic treatment appears to be indicated because of the minor effect upon the prognosis resulting from surgical treatment alone The results of our series indicate that amputation or exarticulation as well as hemipelvectomy or forequarter amputation, offer relatively little to the final outcome in these patients, except for some palliation It has not been shown earlier whether disarticulation at the hip is preferable to amputation through the upper part of the femur for osteosarcomas of the distal portion of the femur (Dahlin 1967) Our data indicate that the more mutilating hip disarticulation does not give a better prognosis than amputation on the proximal femur The possibility of spread of osteosarcoma in the bone marrow must then be checked carefully In the present series, 6 per cent of all patients had local recurrence of the tumor Perfusion of the involved extremity with high doses of cytostatic agents prior to amputation might improve prognosis, as suggested by our data Radical local excision should be employed whenever possible only for tumors not localized to the extremities. Radiation therapy did not affect the prognosis favorably in the present series. Consequently, treatment according to Cade (Cade 1947) cannot be recommended Ten patients of our series had undergone pulmonary resection because of metastases occurring after the primary

significantly lower 5-year survival rate than those who primarily were treated surgically

Chemotherapy with cyclophosphamide was given as an adjuvant after amputation in a limited number of patients Although the data did not demonstrate a significant effect of this treatment upon the prognosis, a slight tendency towards an improved prognosis was found Ten patients received local perfusion of the involved extremity with very high doses of cyclophosphamide prior to amputation. Three of these patients survived for more than 5 years.

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The prognosis was not significantly affected by the various diagnostic procedures applied It was not possible to demonstrate any positive effect upon the 5 year survival rate of primary surgical treatment subsequent to freeze-section diagnosis in comparison with biopsy and secondary surgical treatment after definite histopathological diagnosis had been obtained It has been recommended that biopsy of suspected lesions should be performed without tourniquet to avo d flushing of the tumor cells from the marrow cavity (Allen & Stevens 1973)

Sweden 1959–1965, Stockholm, Göteborgs
et-trycken AB
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ogenic sarcoma A follow-up study of the
94 cases observed at the M
General Hospital from 19
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pondence to S-E Larsson, Department of Orthopaedic Surgery, University
ea, Sweden.

neoplasm had been treated The results obtained supported the view that this kind of treatment is indicated in cases with solitary metastases appearing 1 year after radical treatment of the primary lesion The possibility of metastatic spread of osteosarcoma to other locations in the skeleton should then be examined thoroughly This occurred in 14 per cent of all patients of our series, in the majority of the patients later than 6 months from the time of diagnosis.

REFERENCES

Allen C V & Stevens, K R (1973) Preoperative irradiation for osteogenic sarcoma *Cancer* **31**, 1364–1366

Angsmark G (1969) *Statistisk inferens* Lund Sweden Student litteratur

Cade S (1947) Symposium Primary malignant tumors of bone *Brit J Radiol* **20**, 10–30

Campbell, C J Cohen J & Enneking W F (1975) New therapies for osteogenic sarcoma *J Bone Jt Surg* **57** A 143–144 (Editorial)

Cramer H (1954) *Mathematical methods of statistics* Princeton University Press, Princeton.

Coley B L. & Pool J L. (1940) Factors influencing the prognosis in osteogenic sarcoma *Ann Surg* **112**, 1114–1128

Cortes, E P Holland J F Wang J J Sinks L. F Blom J Senn H Bank, A. & Glidewell O (1974) Amputation and adriamycin in primary osteosarcoma *New Engl J Med* **291**, 998–1001

Dahlin D C & Coventry M B (1967) Osteogenic sarcoma A study of six hundred cases. *J Bone Jt Surg* **49** A 101–110

Dahlin D C (1967) *Bone tumors General aspects and data on 3 987 cases* 2nd Ed Charles C Thomas, Springfield Illinois.

Editorial (1974) A giant step forward if *New Engl J Med* **291**, 1029 1031

Jaffe H L. & Selin, G (1951) Tumors of bones and joints *Bull N Y Acad Med* **27**, 165–174

Jaffe H L (1958) *Tumors and tumorous conditions of the bones and joints* Philadelphia Lea and Febiger

Larsson S (1971) Completeness and reliability of lung cancer registration in the Swedish Cancer Registry *Acta path microbiol scand* **79** A 389 398

Larsson, S-E. & Lorentzon R. (1974a) The geographic variation of the incidence malignant primary bone tumors in Sweden. *Bone Jt Surg* **56**-A, 592–600

Larsson S-E & Lorentzon, R. (1974b) The incidence of malignant primary bone tumours in relation to age, sex and site A study of osteogenic sarcoma, chondrosarcoma and Ewing's sarcoma diagnosed in Sweden from 1958 to 1968 *J Bone Jt Surg* **56**-B 534-540

Lockshin, M D & Higgins, J T T (1968) Prognosis in osteogenic sarcomas. *Clin Orthop* **58**, 85–103

McKenna R J., Schwinn, C. P., Soong K. Y & Higinbotham, N L (1964) Osteogenic sarcoma arising in Paget's disease *Cancer* **17**, [illegible]

McKenna R. J., Schwinn C P Soong K Y & Higinbotham N L. (1966) Sarcomata of the osteogenic series (osteosarcoma fibrosarcoma chondrosarcoma parosteal osteogenic sarcoma and sarcomata arising in abnormal bone) An analysis of 552 cases. *J Bone Jt Surg* **48**-A 1–26

Neff J R & Enneking W F (1975) Adoptive immunotherapy in primary osteosarcoma. An interim report *J Bone Jt Surg* **57** A, 145 148

Nilsonne U., Jacobsson P & Strander H (1975) Osteosarkombehandling med interferon och amputation eller lokal resektion. *Acta Soc Med Suecanae* **84**, 376

Pratt C B Hustu H O & Shanks, E (1974) *Cyclic multiple drug adjuvant chemotherapy for osteosarcoma* *Proc Amer Ass Cancer Res* **15**, 19

Price C H G (1961) Osteogenic sarcoma An analysis of survival and its relationship to histological grading and structure *J Bone Jt Surg* **42** B 300-313

Price C. H G (1962) The incidence of osteogenic [illegible] Paget's disease [illegible] 16. [illegible] sarcoma

Pri [illegible]

Simmons, C. C. (1939) Bone sarcoma Factors influencing prognosis *Surg Gynec Obstet* **68** 67–75

Southam C M Marcove R Mike V., Levin, [illegible]

Sutow W W Sullivan [illegible] (1974) Adjuvant chemotherapy in primary treatment of osteogenic sarcoma. *Proc Amer Ass Cancer Res* **15**, 20

Swedish National Board of Health and Welfare The Cancer Registry Cancer incidence in



Figure 1 Case A Typical facial features (nasal depression, hypertelorism, frontal prominence, ample cranium)



Figure 2 Case A Lateral view of facial features

Hips Bilateral luxation (Figure 4), no pain Acceptable mobility, flexion to 90° on the right and to 80° on the left. External rotation deformity in the left hip, unlimited marching radius

Knees On the right side, good mobility without deformities. On the left side, complete extension, flexion to 10°, rotation of tibia on femur with luxation (Figure 5) Bilateral patellar hypoplasia

Feet Left pes equino-varo-adductus right pes plano-valgus Both feet painless.

Case B J.A.P A, male, 14 years old born at term forceps. Defects observed since birth One parent affected (Case A)

Examination

Typical facial features (Figure 6)

Shoulders Limitation of mobility, no luxation

Elbows Bilateral contracture in 90° flexion Flexion of 60° in the right elbow and 25° in the left elbow Bilateral luxation since birth (Figure 7).

Hands and wrists No deformities, good mobility

Neck Slight left torticollis.

Vertebral column Normal save for discrete dorso-lumbar scoliosis.

Hips Good mobility, flexion to 100° bilaterally No contractures or deformities. At present, bilateral subluxation (Figures 8 and 9)

Knees No deformities and good mobility on the right side On the left side, flexion to 25° and complete extension

Feet Right pes plano-valgus left pes equino-varo-adductus with marked deformity (Figure 10)

Case C M I P A, female, 11 years old born at term, breech presentation Deformities observed since birth Sister of case B and daughter of case A

Examination

Typical facial features (Figure 11).

Shoulders Normal

Elbows Bilateral limitation of extension by about 5 to 10° Bilateral luxation of caput

Hands Normal

Neck Right moderate torticollis.

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LARSEN'S SYNDROME

Report of Three Cases in the One Family, Mother and Two Offspring

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Three cases are presented of the very rare Larsen s syndrome being on the second report in the literature of concomitant involvement of pare (the mother in this instance) and offspring (two children) (see al Haberman et al 1976)

The only therapeutic procedure that is applicable i e surgery has giv only mediocre results over an evolutive period of 8 to 9 years (in case C

We have not been able to demonstrate analytical or histologic abnormalities that might provide a diagnostic clue so that th aetiopathogeny of the disorder remains unknown

Key words Larsen's syndrome, articular luxations heredity

Accepted 3 iv 78

Since 1950, when Larsen and co-workers described as a nosological entity the group of signs and symptoms constituting this disorder, very few cases have been reported in the literature, and very few variations have been added to the original clinical, analytical and radiological description

As regards the aetiopathogeny of the disorder, the majority of authors (Almquist et al 1969, Boni et al 1974, Steel & Kohl 1972) concur that it must be a generalized mesenchymal alteration This opinion, however, has not been proven to date

The possible hereditary character of the disorder has also been the subject of discussion, and the cases reported have been inconclusive in this respect Some do not show a hereditary trend (Larsen et al 1950, Lee 1973), some exhibit recessive heredity (Curtis & Fisher 1970, Steel & Kohl 1972, Latta et al 1971), and some show definite dominant heredity (McFarlane 1947)

In the cases we now present there is t doubt about the hereditary characteristic but it has not been possible to determine th responsible gene and the type of heredity

CASE REPORTS

Case A M I A A, female 34 years old bo normally at term after an uneventful pregnan Defects observed since her birth. No famil H sband co

Examination

Typical facial features (Figures 1 and 2)

Shoulder good mobility, no pain

Elbows Complete flexion Bilateral limitation extension of 20 to 30° Bilateral luxation (Fig 3)

Hands Short fingernails otherwise normal

Vertebral column Moderate right dorso-lumb scoliosis (sleeps with a stiff board under t mattress)



6 Case B Typical facial features Discrete left tort collis

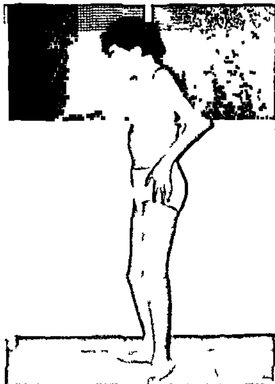


Figure 7 Case B Bilateral flexion contracture of the elbows and visible deformities of the left foot



Figure 8 Case B Hips (1966 age 4 years)



Figure 9 Case B Hips at present Bilateral subluxation



Figure 3 Case A Left elbow Superior cubito humeral and radio-cubital luxation The disorder is bilateral



Figure 5 Case A Left knee Femoro-ti luxation



Figure 4 Case A l Bilateral luxation.

Table 1 Typical deformities

	Case A	Case B	Case C
ˈrantum			
lus	–	–	–
defect	–	–	–
depression	+	+	+
ism	+	+	+
ˡ prominence	+	–	–
cular luxations			
es	+	+	+
ı	+	Subluxation	+
	+	+	+
ulders	–	–	–
ows	+	+	Subluxation of the caput radii
sts and hands			
uple carpal ossifying nuclei	+	+	+
rphalangic luxations	–	+	–
r anomalies (supernumerary gits, syndactyly, "delta" alanges)	–	–	–
ebral column			
iosis	+	±	+
mental anomalies (pina bifida)	+	+	+
rologic disorders	–	–	–
ers			
ble ossification nucleus in e calcaneum	Not able to be evaluated due to definitive fusion	+	
erlaxitude	–	–	
tal retardation	–	–	–

s, or present
)
iscrete

age 2 years Right hip, open reduction wed by pelvi-pedic plaster cast iction was impossible, and the luxation ists to date, with deformity of the femoral t, but with acceptable function
t all surgical procedures, the pathological y of the soft tissue samples was in-lusive as to diagnosis

LABORATORY RESULTS

Case A

Blood (white and red cell count, differential white cell count, erythrocyte sedimentation rate) normal Urine analysis and urinary sediment without pathological findings



Figure 10 Case B Feet at present Marked deformities

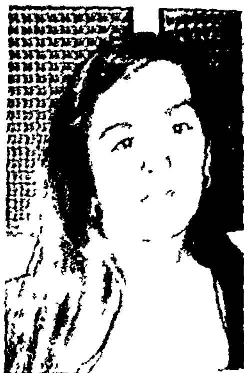


Figure 11 Case C Typical facial features, Marked right torticollis

Vertebral column Normal save for slight right dorsal structural scoliosis

Hips Bilateral luxation Flexion contracture of 20° bilaterally Limited mobility with flexion to 70° on the right and 80° on the left

Knees On the right side flexion contracture of 20° flexion to 20° On the left side complete extension flexion to 15° Discrete deformities.

Lower extremities Dismetry with shortening by 2 5 cm of the left lower extremity

Feet Right pes plano-valgus, left pes equino-varo-adductus.

SURGICAL PROCEDURES

Case A

On the left foot The patient does not remember date or type of procedure

Case B

At 18 months, on the left foot at 24 months, on the right foot and at 36 months on the left knee

All these procedures were carried out prior to the patient's first visit to our hospital so that we lack all data In any case, they must be considered as failures on the evidence of the present state of the areas involved.

At age 6 years Sternocleidomastoideal tenotomy because of congenital left side torticollis The torticollis persists at present although it is markedly reduced

Case C

At age 12 months Right knee open reduction of the luxation stabilization with Kirschner wires, and lengthening of the quadriceps femoris thereafter postural plaster cast On the left knee a similar procedure save for lengthening of the quadriceps which was not carried out. At present there is no luxation (which was so evident before surgery) although discrete postural defects persist and there is very limited mobility

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TELANGIECTATIC OSTEOSARCOMA

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Of the 242 cases of osteosarcoma recorded in the Swedish Cancer Registry for the years 1958 through 1968 only one was found to represent telangiectatic osteosarcoma Another case was recently diagnosed in our department The characteristic morphologic features of these neoplasms were anaplastic stroma high mitotic activity osteo d formation, widely anastomos ng blood spaces, and alkaline phosphatase activ ty The ex perience gathered indicates that telangiectatic osteosarcoma constitutes a histopathologic variant of genuine osteosarcoma with a serious prognosis, necessitating the same kind of treatment as for the genuine tumour

Key words bone neoplasms diagnosis telangiectatic histopathology

Accepted 21 iii 78

…ions differ in the literature as to the …tence of a special type of osteosarcoma …h merits the designation telangiectatic …osarcoma, and the clinical significance of … kind of tumour is also disputed It is … known that differentiation between …giectatic osteosarcoma and other bone …ms with rich vascularization often is …ult, and this is particularly true for the …rentiation between telangiectatic osteo…oma and aneurysmal bone cysts. Because …hese difficulties in differential diagnosis, …er et al (1977) used computerized dis…inant analysis for the study of nuclear … mitotic index, cellularity and nuclear …-content and thus facilitated differentia… between these tumours

…he prognosis of telangiectatic osteosar…a has been reported not to differ from … of other kinds of osteosarcoma (Jaffe …5 Marcove et al 1970 Farr et al. 1974 …suno et al. 1976) Spjut et al (1970) …d no need for subclassification of osteosarcoma into sclerosing osteolytic telangiectatic or medullary types because of a lack of prognostic significance of such a differentiation

Because of the existence of these differing opinions and diagnostic difficulties we found it worthwhile in our studies of malignant primary bone tumours, to pay attention to tumours which might represent telangiectatic osteosarcomas. Among all the tumours which we have studied there have only been two which are of interest in this context. These cases are reviewed in the present study

PATIENTS AND METHODS

Case 1 was recently treated at our clinic and Case 2 was found during our review of all osteosarcomas recorded in the Swedish Cancer Registry from 1958 through 1968 (Larsson et al. 1978).

Case reports

Patient 1 A 14-year-old boy was admitted on January 9 1976 because of pain in the

…orted by grants from the Swedish Cancer …ety (No. 711 B77-05XC).

Urinary mucopolysaccharides 26 U c.p c per gramme of creatinine (normal) Blood biochemistry in the SMA 12 analytical series (transaminases, lactic dehydrogenase, alkaline phosphatase, albumin, bilirubin, total proteins cholesterol, calcium inorganic phosphorus, uric acid, blood urea nitrogen, glucose) within normal ranges. Karyotype 46 XX (normal)

Case B

Blood, urine and urinary sediment (as above) normal, blood biochemistry (as above) Alkaline phosphatase 204 mU per millilitre, inorganic phosphorus 5 6 mg per 100 millilitres the remainder of values within normal ranges. Urinary mucopolysaccharides 147 2 U c.p c per gramme of creatinine Karyotype 46 XYq (normal)

Case C

Blood, urine and urinary sediment (as above) normal, blood biochemistry (as above) Alkaline phosphatase 147 mU per millilitre, inorganic phosphorus 5 5 mg per 100 millilitres, the remainder of values within normal ranges. Urinary mucopolysaccharides 76 3 U c.p.c. per gramme of creatinine Karyotype 46 XX (normal)

DISCUSSION

In the cases presented here there is no doubt as to the presence of hereditary factors which are not always present in this syndrome However, the analytical studies performed yielded normal results, as in practically all cases in the literature, so that the aetiopathogeny of the disorder remains unknown

It is interesting to point out the absence of pain or neurological signs in spite of the ver marked morphological alterations.

Furthermore, ambulation is no problem i the three cases presented, crutches, canes o other aids are not required The marchir radius is not limited

Surgery has only a relatively limited role i the treatment of this disorder Apart from th technical difficulties involved recurrences ar residual joint rigidity are frequent encountered We are therefore faced with nosological entity presenting great difficulti from the viewpoint of medico-surgical trea ment

REFERENCES

Almquist E A. Gordon, L. H & Blue A. (1969) Congenital dislocation of the head of radius. *J Bone Jt Surg* 51 A 1118–1127

Boni, M., Lenzi & Silva (1974) Enfermedad Larsen (Un Sindrome polimorfo) *Rev Ort Traum (Madr)* 1, 261–272.

Curtis, B H & Fisher R L (1970) Herita congenital tibio-femoral subluxation. Clin features and surgical treatment. *J Bone Surg* 52 A 1104–1114

Habermann E T Sterling A. & Dennis, R (1976) Larsen's syndrome a heritable disor *J Bone Jt Surg* 58-A, 558–561

Larsen, J L, Schottstaed E R. & Bost, F (1950) Multiple congenital dislocati associated with characteristic fa abnormality *J Pediat.* 37, 574–581

Latta R. S Graham, C B & Aase J (19 Larsen's syndrome A skeletal displasia w multiple joint dislocation and unusual facies *Pediat* 78, 291–298

Lee, P A. (1973) Multiple joint dislocations peculiar facies. *Amer J Dis Child.* 1 828–830

McFarlane A L (1947) A report of four case congenital genu recurvatum occurring in family *Brit J Surg* 34, 388–391

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. However on April 3, 1965, pulmonary genograms revealed the occurrence of stases. Despite palliative chemotherapy with phosphamide there was progression of the static lesions and the patient died on July 9, in pulmonary insufficiency

needle aspiration biopsy

al obtained at fine needle aspiration biopsy e 3) from patient 1 disclosed sheets of polymorphous cells Some of these were of spindle-shaped, fibroblastic type, whereas were rounded oval or irregular (Figure 3A) hromatin density of the nuclei varied One re nuclei of varying size could be observed ucleoli were medium sized and moderately t. Mitotic figures were seen among the orphous cells (Figure 3B) The amount of asm varied, in most cells there was a ate amount of cytoplasm which showed staining Cytoplasmic granulation and ation were seen in some cells

e multinucleated giant-cells were en- red (Figure 3C) The nuclei were usually d or oval and varied slightly in size and g affinity Rather small and moderately t nucleoli were observed in these cells. A moderately dense cytoplasm with fine granulation was seen The outline of the giant-cells was usually irregular



e 3A Fine needle aspiration biopsy showing orphous and polychromatic tumour cells, of which are spindle shaped May wald Giemsa stain × 520 (patient 1)

3B Mitotic figure in one tumour cell. Grunwald Giemsa stain × 560 (patient 1)

3C Multinucleated giant-cell with d or oval nuclei and a moderate amount of asm May-Grunwald Giemsa stain × 520 t 1)

Light microscopy

The tumours from both patients were fixed in 10 per cent neutral formalin The following stains were applied haematoxylin-eosin van Gieson s stain periodic acid-Schiff (PAS) and Laidlaw's silver impregnation In addition alkaline phos phatase activity was studied using the method of Barka & Andersson (1963)

At re-examination, essentially similar findings were made in both cases. Low power field ex amination disclosed polymorphous tumours with a rich number of widely anastomosing blood spaces of varying size and shape The solid areas exhibited osteoid formation (Figure 4) The amount of osteoid varied considerably in different parts of the same tumour Tumour bone or cartilage were not seen

The solid areas were mainly composed of polygonal cells with a moderate or high poly- morphism In addition some areas exhibited

the nuclear membranes distinct Mitotic figures were frequently encountered Many of these were atypical.

A few multinucleated giant-cells were observed (Figure 6) They possessed medium-sized rounded or oval nuclei with moderately distinct chromatin and medium sized nucleoli The cytoplasm exhibited a moderate density and occasionally small vacuoles The outline was usually irregular

The blood spaces varied considerably in size

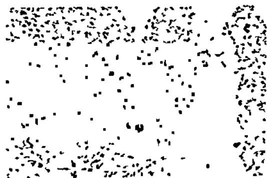


Figure 4 Blood spaces containing some seemingl desquamated tumour cells Osteoid is seen in solid areas Haematoxylin-eosin × 80 (pat



Figure 1 Radiographs revealing a destructive lesion involving the medial portion of the distal femur and causing subperiosteal new bone formation (patient 1)



Figure 2 Angiographs showing hypervascul[illegible] with non-homogenous accumulation of co[illegible] medium and a large number of pathologic [illegible] (patient 1)

part of the left knee of 2 months duration. There was no history of antecedent trauma. Physical examination revealed a firm swelling that was fixed to the medial femoral condyle The regional lymph nodes were not involved The erythrocyte sedimentation rate was 55 mm per hour Other routine laboratory analyses were normal.

Roentgenograms showed a 6 cm long destructive lesion in the distal and medial part of the left femur (Figure 1). A soft tissue tumour could be seen outside the area of bone destruction Angiography revealed a highly vascularized tumour with an abundance of tortuous vessels in the destroyed part of the femur, and also in the surrounding soft tissues (Figure 2) A pulmonary roentgenogram and a scintigram of the liver were normal.

Fine needle aspiration biopsy disclosed polymorphous, partly spindle-shaped mesenchymal cells and a few multinucleated giant-cells (see below) [illegible]

performed on the lesion in the distal femur The tumour was so highly vascularized that it was very difficult to achieve haemostasis, and there was a total blood loss of 1 800 ml The histopathological diagnosis was telangiectatic osteosarcoma (see below)

On January 30, 1976 an amputation of the left femur was carried out, 15 cm below the greater trochanter Three weeks postoperatively chemotherapy with Adriamycin[a] was instituted at a dose of 105 mg as single injections given every [illegible] over a 6-week period He was fitted with a [illegible] thesis and could return home

Despite the treatment, roentgenograms rev[illegible] the occurrence of pulmonary metastases [illegible] November 1976 He died in pulmonary in[illegible] ciency on December 27, 1976

Patient 2 A 16-year-old boy was admitted [illegible] February 20, 1965 because of successively [illegible] creasing pain of 14 days duration localized to [illegible] left knee region around the proximal part of [illegible] fibula. Physical examination showed a 10×[illegible] large, tender swelling over the head of the [illegible] fibula There was no involvement of the regi[illegible] lymph nodes. Routine laboratory investigat[illegible] were normal including the sedimentation [illegible] Roentgenograms revealed a destructive le[illegible] involving the whole proximal part of the fibul[illegible] pulmonary roentgenogram was normal.

On March 4, 1965, a cystic chocolate-bro[illegible] easily bleeding soft tumour was excised [illegible] bone was completely destroyed by the tumour [illegible] there was no major extension into the surround[illegible] soft tissues. The operation was performed [illegible] bloodless field There was no excessive blee[illegible] when the tourniquet was released.

The histopathological appearance of [illegible] removed specimen was difficult to interp[illegible] Aneurysmal bone cyst or giant-cell tumour of b[illegible] were considered but the final diagnosis [illegible] telangiectatic osteosarcoma (see below)

Postoperative high-energy radiotherapy [illegible]

The other case was recently diagnosed in our department. Telangiectatic osteosarcoma thus constitutes, at the most, no more than 2 per cent of all types of osteosarcoma With a mean yearly incidence of 2.8 cases of osteosarcoma per million people in Sweden (Larsson & Lorentzon 1974a) telangiectatic osteosarcoma is very rare, the yearly incidence being about 5 6 cases per 100 million people

There was a male predominance with a ratio of 1 9 1 in the series of Farr et al (1974), while for all types of osteosarcoma we found a sex ratio of 1 4 1 (Larsson & Lorentzon 1974b) Except for a less common involvement of the tibia the data published by Farr et al (1974) indicated no difference as regards the clinical course between telangiectatic osteosarcoma and genuine osteosarcoma as a group The cure rate was approximately 18 per cent The clinical [illegible]

[illegible] ing in the knee region, and either increased or normal sedimentation rate Roentgenograms showed a destructive lesion similar to that of genuine osteosarcoma Angiography, carried out in Case 1, showed a highly vascularized tumour The rich vascularization was further demonstrated by the presence of profuse bleeding at biopsy, almost like bleeding directly from the femoral artery Case 2 did not exhibit such profuse bleeding at operation, although, at light microscopy, the tumour was as vascularized as that of Case 1 The use of a tourniquet in Case 2 and the more peripheral location of the lesion in the proximal fibula might explain the observed difference in bleeding from the tumours.

Characteristic light microscopic features of the tumours in our cases were anaplastic stroma, high mitotic activity, osteoid formation, widely anastomosing blood spaces and alkaline phosphatase activity Multinucleated giant-cells were rather sparsely represented The morphological findings and the clinical course indicate malignancy Because of the light microscopic characteristics the histopathological diagnoses which primarily should be considered are osteogenic sarcoma on the one hand and aneurysmal bone cyst on the other hand Although genuine giant-cell tumours may produce osteoid (Murphy & Ackerman 1956, Shuffstall & Gregory 1953, Williams et al 1954) and also may be rich in blood vessels, there was no evidence in our cases of giant-cell tumour The anaplasia in our tumours was characteristic of a sarcomatous tumour such as osteosarcoma, and reduced the possibility of it being an aneurysmal bone cyst. This opinion is also held by Clough & Price (1968) and Tillman et al (1968) The latter authors have also suggested that the presence of irregular tumour osteoid indicates telangiectatic osteosarcoma rather than aneurysmal bone cyst Based upon these findings we maintain that telangiectatic osteosarcoma can be differentiated from other bone lesions. The alkaline phosphatase activity found in our tumours also suggests osteosarcoma Fine needle aspiration biopsy suggested malignant bone tumour in our cases but did not help in the differentiation of the lesion

Reed & Rothenberg (1964) have proposed that the vascularity pattern of aneurysmal bone cysts is a non-specific reaction representing a primary lesion, whereas vascularity of other bone tumours represents a late secondary change The finding in our cases of seemingly desquamated tumour cells in the lumina, and the absence in many blood spaces of an endothelial lining, might indicate a secondary nature of the blood spaces. It is of interest that we have observed a similar rich vascularization in experimentally produced mouse osteosarcoma (Larsson et al unpublished) Osteosarcoma containing a rich amount of blood filled cysts has also been described in a dog (Price & Sumner-Smith 1966)

Angiographically, telangiectatic osteosarcoma is hypervascularized as most of the osteosarcomas Genuine giant-cell tumour of bone and some of the aneurysmal bone cysts are also hypervascularized (Lundstrom et al 1977) which in some cases could make differential diagnosis difficult As in all cases

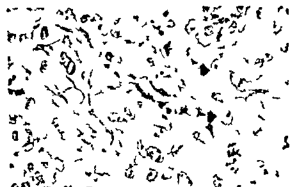


Figure 5 Solid tumour area showing oval or slightly irregular nuclei with one or more distinct nucleoli (arrows) Mitotic figures are seen Haematoxylin eosin × 500 (patient 1)

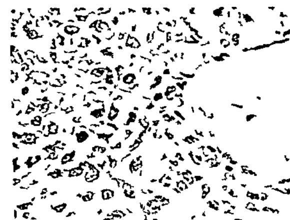


Figure 6 Blood space lined by endothelial like cells The solid area exhibits polymorphism polychromasia one multinucleated giant cell (G) and mitotic figures Haematoxylin eosin × 500 (patient 1)

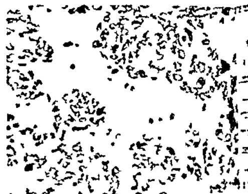


Figure 7 Irregular blood spaces witho endothelial lining Erythrocytes are seen in t lumina The solid areas are moderate polymorphous Van Gieson s stain × 5
(patient 2)

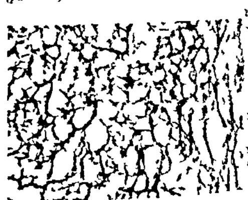


Figure 8 Alkaline phosphatase activity in solu tumour area × 500 (patient 1)

and shape Erythrocytes were found in the lumina (Figure 7) Most blood spaces were lined by flattened cells of endothelial type (Figure 6) whereas no such lining was found in other blood spaces (Figure 7) Still other spaces were surrounded by rounded or cuboidal cells. Evident alkaline phosphatase activity was found in the tumours (Figure 8).

DISCUSSION

Telangiectatic osteosarcoma was considered by Ewing (1922, 1939) to be a distinct clinical and pathological entity However recent reviews (Dahlin 1967, Jaffe 1956 Marcove et al 1970 Price & Sumner Smith 1966 designate telangiectatic osteosarcoma as a histopathological variant of osteosarcoma with no special clinical significance. Th opinion was also supported in the rev ew o Farr and co-workers (1974) The frequency o telangiectatic osteosarcoma has not been deal with in previously published large series o osteosarcoma In the recent study by Far and co-workers (1974) only 29 patients wit telangiectatic osteosarcoma could be found among a total of 1 480 cases of osteosarcoma i e 2 per cent In our review (Larsson et al 1978) of all 242 cases of osteosarcom recorded in the Swedish Cancer Registr during the years 1958 through 1968 w found only one case which warranted sub classification as telangiectatic osteosarcom

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...STRUCTION OF A TUBERCULOUS THUMB BY ... BONE GRAFTING

Report

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Tuberculosis with secondary staphylococcal infection destroyed the right thumb and index phalanges of a 24-year-old farmer. Four months after starting antibiotic therapy the index finger was amputated, and the thumb reconstructed by excising the disorganized phalanges and transferring the index metacarpal as a free graft to replace them. No previous report of this technique has been traced. A concurrent infection of the patient's left tarsus was treated by triple arthrodesis.

Key words: tuberculous thumb, reconstruction, index metacarpal, free graft

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...SE REPORT

..., a 24-year-old farmer ...

... tuberculous osteitis with secondary ...tion by *Staphylococcus aureus*. Chemotherapy ... Streptomycin, Myanbutol and Rifampicin was ...ted, but 2 months later, although his general ...tion was considered improved, his hand and ... remained unchanged.

The state of his right hand at that time is ... in Figure 1. The middle phalanx of the ... finger and proximal phalanx of the thumb ... completely disorganized, and the bases of ... distal phalanges, and the head of the ...mal index phalanx were destroyed by the in...tion. Multiple sinuses were present.

...s general condition was good, and there were ... signs of tuberculosis elsewhere but his ...ocyte sedimentation rate (Westergren) was ... millimetres in the first hour.

...hemotherapy was continued and the affected ... immobilized in a plaster cast. Two months ... all sinuses were healed and his sedimentation ... fell to 25.

Because of the extensive phalangeal destruction and consequent instability of the right thumb and index finger it was decided to sacrifice the latter and reconstruct the thumb, the operation being carried out on June 7th, 1972, some 6 months after the first hand symptoms. Under general anaesthesia and pneumatic tourniquet a racket incision was made, encircling the base of the index finger, with its handle extending proximally along



Figure 1. The hand 4 months after the onset of symptoms.

of malignant bone tumour, the final diagnosis should always be based upon a thorough evaluation of all clinical, roentgenographical and histopathological data In view of the differences with regard to treatment and prognosis, the differentiation of telangiectatic osteosarcoma from other bone lesions, particularly benign lesions such as aneurysmal bone cyst, is very important From our experience we agree with Farr et al (1974) that telangiectatic osteosarcoma constitutes a histologic variant of genuine osteosarcoma, with a similar serious prognosis, necessitating the same kind of treatment

REFERENCES

Barka, T & Anderson, P J (1963) *Histochemistry Theory, practice and bibliography*, p 240 Harper and Row, Publ Inc, New York, Evanston and London

Clough, J R. & Price C H G (1968) Aneurysmal bone cysts *J Bone Jt Surg* 50 B, 116–127

Dahlin, D C (1967) *Bone tumors* 2nd ed Charles C Thomas, Springfield, Ill

Ewing, J (1922) A review and classification of bone sarcomas. *Arch Surg* 4, 485–533

Ewing, J (1939) A review of the classification of bone tumors *Bull Amer Coll Surg* 24, 290–295

Farr G H Huvos, A G, Marcove, R C, Higinbotham N L & Foote, Jr, F W (1974) Telangiectatic osteogenic sarcoma A review of twenty-eight cases *Cancer* 34, 1150–1158

Jaffe, H L (1956) Osteogenic sarcoma of bone *Clin Orthop* 7, 27–39

Larsson S-E & Lorentzon R (1974a) The geographic variation of the incidence of malignant primary bone tumors in Sweden *J Bone Jt Surg* 56-A 592–600

Larsson, S-E & Lorentzon R (1974b) The incidence of malignant primary bone tumours in relation to age, sex and site *J B[illegible] Surg* 56-B, 534–540

Larsson, S-E, Lorentzon, R., Wedrén, [illegible] *scand* 49, 571–581

Lundström, B, Lorentzon, R, Larsson, S [illegible] Boquist, L. (1977) Angiography in gia[illegible] tumours of bone *Acta radiol. (Stockh[illegible]* 541–553

Marcove, R C., Miké, V, Hajek J V., [illegible] A. G & Hutter, R V P (1970) Oste[illegible] sarcoma under the age of twenty-one [illegible] review of one hundred and forty five op[illegible] cases *J Bone Jt Surg* 52 A, 411–423

Matsuno, T, Unni, K. K., McLeod, R. [illegible]

Mc[illegible] and malignant giant-cell tumors of [illegible] *Cancer* 9, 317–323

Price, C H G & Sumner Smith G [illegible] Malignant bone aneurysm in a dog [illegible] unusual example of osteosarcoma *Brit.* [illegible] 122, 51–54

Reed, R J & Rothenberg, M (1964) Lesio[illegible] bone that may be confused with aneu[illegible] bone cyst *Clin Orthop* 35, 150–162

Ruiter, D J., Cornelisse, C. J, van Rijssel, T [illegible] & van der Velde, E. A (1977) Aneurysmal [illegible] cyst and telangiectatic osteosarcoma [illegible] histopathological and morphometric [illegible] *Virchows Arch path anat* 373, 311–325

Shuffstall, R M & Gregory J E (1953) O[illegible]

Sp[illegible] Ackerman L V (19[illegible]) [illegible] *cartilage Atlas of tumor pathology* S[illegible] Fasc 5 Armed Forces Institute of Path[illegible] Washington

Tillmann B P, Dahlin, D C, Lipscomb P [illegible] Stewart, J F (1968) Aneurysmal bone cy[illegible] analysis of ninety five cases *Mayo Clin* [illegible] 43, 478–495

Williams, R R, Dahlin D C & Ghormley [illegible] (1954) Giant-cell tumor of bone *Canc[illegible]* 764–769

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orthop scand. 49 597–599 1978

CUTANEOUS PINNING OF SUPRACONDYLAR CTURES OF THE HUMERUS

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ebro Denmark.

Six cases of supracondylar fracture of the humerus in children were treated by closed reduction and percutaneous pinning with two Kirschner wires inserted laterally through the capitellum of the humerus. This treatment has the same advantages as the commonly used percutaneous pinning with crossed Kirschner wires inserted through the epicondyles of the humerus, and it further eliminates the risk of damaging the ulnar nerve by the insertion of the medial Kirschner wire

Key words percutaneous lateral pinning supracondylar fractures of the humerus, ulnar nerve lesion

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racondylar fracture of the humerus in dren, usually produced by a fall on the tretched arm, is a common fracture een the ages of 4 and 10 years. In nearly er cent it is an extension fracture with posteriorly displaced distal fragment unt 1954 Holmberg 1945, Høyer 1952, son Jones 1976).

veral different methods of treatment been recommended

losed reduction and plaster fixation
losed reduction and traction
losed reduction and percutaneous nning
pen reduction and osteosynthesis.

veral modifications of these methods have described (Blount 1954 Dunlop 1939, El-kawi & Fattah 1965, Hagen 1964, Høyer Sandegård 1943, Swenson 1948)

us report concerns six cases of condylar fracture of the humerus in hood fixed with two percutaneous hner wires inserted laterally through the capitellum of the humerus after closed reduction, as described by Fowles & Kassab (1974)

PATIENTS AND METHODS

During the period 1974–1977 33 children between the ages of 4 and 15 years with displaced supracondylar fractures of the humerus were treated in Holstebro Central Hospital, Orthopaedic Surgical Department

Fifteen were treated with closed reduction and plaster and one with skeletal traction Seventeen were osteosynthesized nine after open and eight after closed reduction The closed reduction was in two cases followed by percutaneous fixation with two crossed Kirschner wires through the epicondyles, and in six cases with percutaneous pinning with two Kirschner wires inserted laterally through the capitellum of the humerus. These six fractures were all according to the classification of Holmberg (1945), type 4 fractures. Five were treated as emergencies and one after 4 hours due to insufficient conservative treatm



Figure 2 Four months postoperatively showing rapid recovery of function.



Figure 3 Four years after operation showing [illegible] *corporation of graft*

the radial side of the second metacarpal to its base The finger was disarticulated at its metacarpo-phalangeal joint and the distal four fifths of its metacarpal removed subperiosteally Through a longitudinal incision on the ulnar side of the thumb the remains of the proximal phalanx the base of the distal phalanx and the head of the first metacarpal were excised The freed index metacarpal was trimmed by removing the distal part of its head to make a tight fit between the cut ends of the thumb metacarpal and distal phalanx It was inserted with its original distal (broad) end facing proximally and no internal fixation was required

The forearm wrist and reconstructed thumb were immobilized in a plaster cast for 3 weeks whereafter mobilizing exercises were started Three months later excellent function was present with good opposition and pinch (Figure 2) The patient was last seen 4 years postoperatively when he was doing his normal farm work without significant disability X ray at this time [illegible] complete incorporation of the graft (Figure 3)

COMMENT

Pollicization using the index finger or [illegible] the index ray, is well established for [illegible] the amputated or congenitally absent [illegible] but the free graft reconstruction des[illegible] here as a method of replacing necrotic [illegible] does not appear to have been record[illegible] viously

It is applicable only in cases of [illegible] destruction with intact soft tissue [illegible] biologically it is comparable with the [illegible] free rib grafts to fill the gap between [illegible] vertebral bodies after anterior debride[illegible] the tuberculous spine

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is superior to conservative treatment (Flynn et al 1974, Haddad et al 1970)

However, the insertion of the medial Kirschner wire involves the risk of injuring the ulnar nerve due to difficulties in locating it because of fracture oedema This fact may lead to open reduction of the fracture, enlarging the intervention considerably (Gruber & Hudson 1964, Sandegård 1943) Furthermore, the rarely occurring congenital anteposition of the ulnar nerve heightens the risk of injuring the nerve

Percutaneous lateral pinning seems to offer the same advantages as the usually performed method with crossed Kirschner wires, i e, stable fixation of the fracture, short hospitalization, short immobilization, few operative complications and good end results Finally both methods are quick and simple surgical interventions However, in addition percutaneous lateral pinning has the advantage of eliminating the risk of lesion to the ulnar nerve when inserting the medial Kirschner wire (Flynn et al 1974, Haddad et al 1970, Jones 1967, Swenson 1943)

Postoperative affection of the ulnar nerve was found in both cases treated with crossed percutaneous pinning in this report In one of the cases the ulnar nerve was partially transected when the medial Kirschner wire was removed. After primary suture the nerve function was almost fully restored In the other case paresis of the ulnar nerve was observed for 3 months after the operation These ulnar nerve complications could have been avoided by using percutaneous lateral pinning

REFERENCES

Blount, W P (1954) *Fractures in children* pp 26–28 The Williams and Wilkins Co Baltimore

Dunlop, J (1939) Transcondylar fractures of the humerus in childhood *J Bone Jt Surg* **21**, 59–73

El Sharkawi, A H & Fattah H A (1965) Treatment of displaced supracondylar fractures of the humerus in full extension and supination *J Bone Jt Surg* 47-B 273 279

Flynn, J C, Matthews J G & Benoit R L (1974) Blind pinning of displaced supra condylar fractures of the humerus in children *J Bone Jt Surg* 56-A 263–271

Fowles, J V & Kassab M T (1974) Displaced supracondylar fractures of the elbow in children *J Bone Jt Surg* 56-B 490–500

Gruber, M A & Hudson O C (1964) Supracondylar fractures of the humerus in childhood *J Bone Jt Surg* 46-A 1245–1252

Haddad R J, Jr, Saer, J K & Riordan D C (1970) Percutaneous pinning of displaced supracondylar fractures of the elbow in children *Clin Orthop* **71**, 112–117

Hagen R (1964) Skin traction treatment of supracondylar fractures of the humerus in children A ten year review *Acta orthop scand* **35**, 138–148

Høyer, A (1952) Treatment of supracondylar fracture of the humerus by skeletal traction in an abduction splint *J Bone Jt Surg* 34-A 623–637

Holmberg L (1945) Fractures of the distal end of the humerus in children. *Acta chir scand*, Suppl. 103 92, 1–69

Jones, K G (1967) Percutaneous pin fixation of fractures of the lower end of the humerus *Clin Orthop* **50**, 53–69

Sandegård E (1943) Fracture of the lower end of the humerus in children Treatment and end results. *Acta chir scand* **89**, 1–16

Swenson, A L (1948) The treatment of supracondylar fractures of the humerus by Kirschner wire transfixion *J Bone Jt Surg* 30-A, 993–997

Watson-Jones, R (1976) *Fractures and joint injuries*, 5th ed pp 611–614 E. & S Livingstone Ltd, Edinburgh and London.

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Figure 1a, b AP and lateral radiographs showing a displaced supracondylar fracture of the humerus in a boy 8 years old



Figure 2a, b AP and lateral radiographs of th same elbow as shown in Figure 1, after reduction pinning and application of a plaster splint.

The surgical interventions are performed under general anaesthesia and with the aid of an X-ray with TV-amplifier The fracture is reduced as described by Watson-Jones (1976)

The surgeon then with one hand holds the reduced fracture Having palpated the capitellum of the humerus just laterally to the olecranon a Kirschner wire (size 1 25 mm in diameter) is inserted percutaneously using an automatic drill between the capitellum and the trochlea of the humerus through the fracture about 5 cm up into the medullary canal The second wire is inserted at an angle of 30 degrees, close to the first, and

[illegible]

with the elbow flexed to 90 degrees and the forearm in neutral position.

After the operation the patient is confined to bed with the arm elevated for 24 hours All the patients were out of bed on the second day and were discharged 2 to 5 days postoperatively

X-ray examination was performed 1 and 3 weeks after the operation. All fractures had healed after 3 weeks, when plaster and Kirschner wires were removed in the out patient clinic without the use of local anaesthesia Rehabilitation of the mobility of the elbow was started either by self-training (3 patients) or with the help of a physiotherapist (3 patients)

The children were re-examined 5 to 10 weeks postoperatively (mean 7 weeks) and finally followed up after 6 months to 3 years (mean 2 years) The results were classified according to Fowles & Kassab (1974)

Excellent a normal hand and arm

Good either a deficit of less than 20 degrees in the range of movement of the elbow or a change in the carrying angle of less than 10 degrees (if both abnormalities were present the patient wa placed in the next category)

Fair a deficit in the range of movement of le than 20 degrees

Poor the range of movement decreased b more than 50 degrees, or a change in the carryi angle of more than 20 degrees

RESULTS

At the final examination in the open ward th result in two patients could be classified a excellent, three as good and one as fair

Six months to 3 years later the result wa excellent in four cases and good in one cas The child classified as good had a var deformity of 5 degrees.

During the observation period neith neurovascular disturbances nor infectio were observed No subjective discomfort w recorded

One patient, who 10 weeks postoperative was classified as excellent, could not followed up

DISCUSSION

The treatment of supracondylar fractures the humerus in children as described Swenson (1948) and later by Jones (196 with closed reduction followed by fractu fixation with crossed percutaneous Kirsch wires through the epicondyles of t humerus, in several reports has prov



gure 1 A 22 year old man Right shoulder rtical caudo-cranial view Posterior dislocation the humeral head

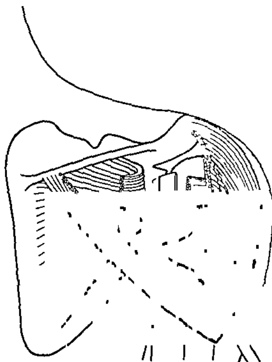
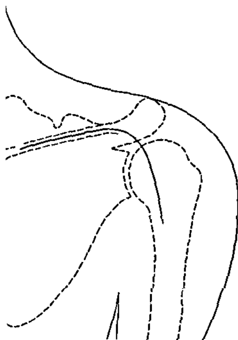


Figure 3 The deltoid is separated from the spine of the scapula and retracted inferiorly The infra spinatus tendon is divided and the graft in position



e 2 Posterior aspect of the right shoulder ng the skin incision

varied, 15 months in one case 30 hs in one case and at least 4 years in cases

vo male patients considered their lders to be completely normal They had a full range of motion and no instability could be provoked Another of the male patients stated that during the first 2–3 years after operation he had experienced only some crepitations in the shoulder but later got a feeling of incipient locking in a certain position of the arm He had no feeling of in stability and thought himself much better than before operation Clinical examination revealed no instability during movement but when the humerus was slightly flexed and inwardly rotated the examinor could force the humeral head somewhat backwards indicating slight instability The sensation the patient thereby felt was not familiar to him The mobility was normal

The patient with general joint laxity con sidered himself definitely improved by the operation even if he experienced some residual instability which could be verified A slightly decreased mobility was noted

The 64-year-old woman reviewed 4 years

Acta orthop scand. 49, 600–603, 1978

IDIOPATHIC POSTERIOR INSTABILITY OF THE SHOULDER JOINT

Results of Operation with Posterior Bone Graft

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Five cases of idiopathic posterior instability of the shoulder joint operatively treated mainly by insertion of a bone graft are reported. The late results are satisfactory

Key words posterior instability, shoulder joint, bone graft

Accepted 1 iv 78

Two main groups of recurrent posterior subluxation or dislocation (instability) of the shoulder joint can be recognized, the posttraumatic and the idiopathic (English & Macnab 1974)

This paper reports the results of an operation for idiopathic instability consisting mainly of insertion of a bone graft

PATIENTS

Four men (age range 18–34 years) and a 64-year-old woman sought medical advice because of instability of the shoulder joint In four cases the symptoms had started after minor or insignificant trauma and in this group there was an 18-year-old male alcoholic who also had general laxity of the joints. The fifth patient, a 34-year-old man had 13 years earlier sustained a football injury which was not severe enough to make him attend a doctor but after which the shoulder symptoms commenced The patients had had symptoms varying from some months to almost 50 years.

Instability of the posterior type was diagnosed at clinical and roentgenological examination (Figure 1) The indication for operation was recurring episodes of painful instability in some cases occurring with increasing frequency One male patient could not reduce the dislocations by himself

OPERATIVE PROCEDURE

The approach is similar to that described by Rowe & Yee (1944), with a skin incision along the spine of the scapula, curving laterally downwards over the posterior aspect of the shoulder joint (Figure 2). The deltoid is separated subperiostally from the spine of the scapula by sharp dissection from the lateral to the medial side where the origin is spared The muscle is retracted inferiorly and the infraspinatus exposed Care is taken not to damage the suprascapular and axillary nerves The infraspinatus tendon and the capsule are divided and the posterior aspect of the glenoid well exposed. About 5 mm from the articular margin a groove is made with an osteotome to receive the transplant, which is taken from the iliac crest The size of the transplant is about 2 × 2.5 cm and it is allowed to project 8–12 mm posteriorly over the articular surface (Figures 3 and 4) It should be placed in the middle of the posterior aspect of the glenoid and not too cranially or caudally in order to minimize the risk of recurrence of the instability The tendon or the capsule is duplicated and the deltoid is reattached Postoperatively the arm is immobilized in neutral position between inward and outward rotation for 4 weeks. Active exercises are then started

RESULTS

At follow-up the patients were examined clinically and roentgenologically Follow up

chosen in four cases out of five and in the fifth only the bone graft was used

The results can be judged as excellent in two cases and very good in one case The other two patients considered themselves definitely improved It is remarkable, however that the woman thought that her shoulder was stable in spite of the instability clearly demonstrable at the clinical examination.

A fairly extensive search of the literature or idiopathic posterior instability of the shoulder joint treated with a posterior bone graft revealed several reports all with favourable results (Hohmann 1933, Asplund 1942, Toumey 1948 Jones 1958 Galli 1959, Mason 1967, Lindholm 1974) but in each report there were only one or two cases and the interval between the operation and the review was often less than a year DePalma (1973) who has had greater experience favoured a combined procedure with a bone graft or osteotomy of the neck of the scapula supplemented by tendon shortening and reported no failures

REFERENCES

Asplund G (1942) Ein operierter Fall von willkurlicher (habituell willkurlicher) hinterer Schulter-gelenksluxation *Acta chir scand* **87,** 103–112

Boyd, H B & Sisk T D (1972) Recurrent posterior dislocation of the shoulder *J Bone Jt Surg* 54 A 779–786

DePalma, A (1973) *Surgery of the shoulder* J B Lippincott Company Philadelphia Toronto

Mason, J H (1967) Posterior dislocation and posterior fracture dislocation of the shoulder A report of 25 cases *Sth med J (Bgham Ala)* **60,** 661–666

Ekman H (1948) A case of habitual posterior subluxation of the shoulder joint operated according to Clairmont Ehrlich *Acta chir scand* **97,** 322 330

English E & Macnab I (1974) Recurrent posterior dislocation of the shoulder *Canad J Surg* **17,** 147–151

Fried A (1949) Habitual posterior dislocation of the shoulder joint *Acta orthop scand* **18,** 329–345

Galli H (1959) Die hintere wiederholte Schulter luxation *Z Orthop* **92,** 97–110

Hindenach J C R (1947) Recurrent posterior dislocation of the shoulder *J Bone Jt Surg* **29,** 582–585

Hohmann G (1933) Zur Behandlung der angeborenen Luxation des Schultergelenks *Der Chirurg* **5,** 409–411

Jones V (1958) Recurrent posterior dislocation of the shoulder *J Bone Jt Surg* 40-B 203–207

Lindholm T S (1974) Recurrent posterior dis location of the shoulder *Acta chir scand* **140,** 101–106

Mclaughlin H L (1962) Posterior dislocation of the shoulder *J Bone Jt Surg* **44** A 1477

Rowe C R & Yee L B K (1944) A posterior approach to the shoulder joint *J Bone Jt Surg* **26,** 580–584

Scott D J (1967) Treatment of recurrent posterior dislocations of the shoulder by glenoplasty *J Bone Jt Surg* **49** A 471–474

Severin E (1954) Anterior and posterior recurrent dislocation of the shoulder *Acta orthop scand* **23,** 14–22

Sjovall H (1944) Fall av spontan subluxation bakat i axelleden opererad enligt Clairmont Ehrlich *Nord Med* **21,** 474–476

Toumey J W (1948) Posterior recurrent disloca tion of the shoulder treated by capsulorrhaphy and iliac bone block *Lahey Clin Bull* **5,** 197 201

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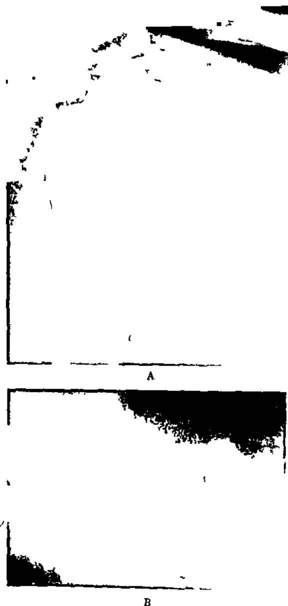


Figure 4 A 34 year old man Postoperative roentgenograms of the right shoulder
(a) A P view The graft is clearly visible through the humeral head
(b) Vertical caudo-cranial view showing the graft and its position in the scapular neck

after operation, was satisfied considered the shoulder stable, painless and with sufficient mobility At clinical examination the humeral head could be seen to bulge backwards during movements either spontaneously or aft slight provocation Inward rotation w moderately decreased, otherwise mobility w normal

In no case did the roentgenological ex amination reveal resorption and di appearance of the graft

DISCUSSION

A division of posterior dislocations and sub luxations of the shoulder into a post traumatic (traumatic) and a idiopathic (atraumatic group seems well founded

The term dislocation is questionabl though a true dislocation with no con between the articular surfaces may occur A "subluxation" with articular contact partially maintained is not unusual The term "instability" covers the various alternative from slight incongruency to complete di tion and has therefore been suggested as a more suitable term (DePalma 1973)

Four of the cases in the present series can be classified as instability of the idiopathic type The aetiology in the case with the football trauma is a little uncertain The trauma seems significant, but a posterior dis location which reduces spontaneously must be due to an inherent tendency to instability It therefore seems reasonable to assume idiopathic instability also in this case

Several operations have been designed for cases where the symptoms indicate surgical intervention Such operations are soft tissue operations (Sjovall 1944, Ekman 1948 Severin 1954, Boyd & Sisk 1972 English & Macnab 1974, Lindholm 1974), skeletal operations such as a posterior bone graft (Asplund 1942, Hindenach 1947, Fried 1949 Lindholm 1974) or an osteotomy of the glenoid cavity (Scott 1967, English & Macnab 1974) and combined procedures (Dimon 1967, Mclaughlin 1962, DePalma 1973) In the present series a combined procedure with a posterior bone graft and a raphe of the infra- spinatus tendon or posterior capsule was

...TERIALS AND METHOD

...terial material

Fourteen lumbar spines from subjects aged ...ween 18 and 73 years were removed during ...tine necropsies. The material was collected ...m cadavers in whom there was no evidence of ...e disease The spines were dissected into joints ...sisting of two vertebra and the intervening ... Of the joints tested, five were L5-S1, six ...e L4-L5 four were L3-L4 and three were L2- ... Table 1 gives details of the specimens tested

...rimental method

...ach joint was stripped of the excess fat and ...scles, but the ligaments and muscles joining the ...tebrae were not disturbed The joint was then ...nted in surgical cement (calestone) and ...pped in polythene to avoid dehydration ...ing mounting care was taken to ensure that ...plane midway through the intervertebral disc was parallel to the end-plates of the containers holding the upper and lower vertebrae This method of mounting helps to ensure that no shear components act on the disc, and so the neural arch is not subjected to backward bending when the subsequent compressive tests are carried out.

Calestone is a stiff material which deforms very little under the forces applied during these tests When hardening it is also exothermic and a stream of cold air was directed onto the specimen during this stage to avoid any damage from the heat generated

In life the intervertebral joints are subjected to varying compressive and shear forces. In these experiments, however, only a pure compressive force was applied to the joint This is not an un physiological situation since mathematical analysis of forces acting on the lumber vertebrae shows that the shear force can be easily counteracted by the muscle attachments to the spinous process (Hutton et al 1977, Cyron 1977)

The compressive tests were carried out using a servo-controlled hydraulic testing machine The upper cross head of the machine incorporated a

Table 1 The details of the results obtained

...up 1

...imen ...ber	Age	Sex	Intervertebral level	Stiffness of the intact joint kN/cm	Stiffness after neural arch fracture kN/cm
	18	F	L3 L4	56 7	56 7
	18	F	L5-S1	27 5	27 5
	26	M	L5 S1	23 6	23 6
	38	M	L3 L4	30 7	30 7
	38	M	L5 S1	21 4	21 4
	44	M	L5 S1	18 8	18 8
	44	M	L4-L5	29 8	29 8
	44	M	L3 L4	27 5	27 5
	44	M	L5-S1	37 3	37 3
	59	F	L3 L4	18 8	18 8

...p 2

...imen ...ber	Age	Sex	Intervertebral level	Stiffness of the intact joint kN/cm	Stiffness after neural arch fracture kN/cm
	18	M	L2 L3	34 9	18 4
	18	M	L4-L5	37 0	27 4
	19	M	L4-L5	29 0	24 7
	37	M	L4-L5	26 1	19 6
	44	M	L2 L3	32 7	27 5
	44	M	L4-L5	30 7	21 9
	46	F	L4-L5	26 0	19 6

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SPONDYLOLYSIS

The Role of the Posterior Elements in Resisting the Intervertebral Compressive Force

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Compressive tests were carried out on cadaveric lumbar intervertebral joints, before and after the neural arch was fractured The results show that although the neural arch can play some part in resisting the intervertebral compressive force, there is no bony contact between the downward projecting tips of the inferior articular processes and the laminae of the vertebra below

Key words spondylolysis, neural arch, lumbar vertebrae, intervertebral joint

Accepted 11 iv 78

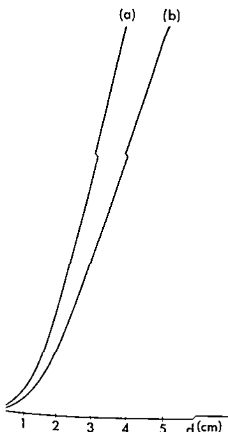
The neural arch of a vertebra articulates with adjacent vertebrae through the apophyseal joints The inferior articular processes hang down from the junction of the pedicles with the neural laminae and, through the articulation, resist forward shear forces acting on the intervertebral joint The mechanics of this passive resistance is complicated by the muscles attached to the neural arch These muscles have a net bracing effect by pulling down on the neural arch and countering any tendency to forward displacement of an upper vertebra on the one below (Cyron 1977, Hutton et al 1977)

The neural arch is clearly subjected to mechanical stress during everyday activities and a fracture of the laminae across the partes interarticulares occurs in about 1 in 20 of the population (Newman 1963, Wiltse et al 1975) This type of fracture, called spondylolysis, is often followed by spondylolisthesis, a forward slip of a vertebra on the one below These conditions are most common at the lumbo-sacral level

The mechanics of spondylolysis as explained above, ascribes the stress on the neural arch as solely due to forces perpendicular to the inferior articular facets acting with muscle forces to produce a critical stress This explanation does not allow the neural arch to take any part in resisting the compressive force acting on the intervertebral joint, in that the facets glide over each other and in no important way do the tips of the inferior articular processes come into contact with the neural laminae of the vertebra below There is an alternative theory

It is suggested that, due to lumbar lordosis, the neural arch of L5 lies in a pincer-like grip between the downward projecting tips of the inferior articular processes of L4 and the upward projecting tips of the superior articular processes of the sacrum In this theory the compressive force transmitted by the intervertebral joints is resisted mainly by the neural arch of L5 (Nathan 1959)

This paper describes experimental work carried out to quantify the role of the neural arch in resisting intervertebral compressive forces



3 *Typical result showing the force/ ...ation characteristics of a lumbar inter ...al joint in group 2 In this group the ...s decreased after the neural arch had been*

...LTS

...xperimental results are summarized in ... 1

... joints were tested to a maximum com... ...ve load of about 5 kN After about ... the graphs became relatively linear up ... maximum load and the slope of this ...n of the graph was measured The slope ...ch case represents the compressive ...ss of the joint (or to be more precise ...mpressive stiffness of the intervertebral ... plus two vertebrae embedded in ...one)

The results fall into two groups as illustrated by Figures 2 and 3 In the first group, consisting of eleven joints the results show some residual deformation between graphs (a) and (b) (Figure 2), although the slope of the main portion of the graphs is the same In the second group, consisting of seven joints, there is a combination of residual deformation and a change in stiffness Graph (b) in Figure 3 illustrates a result for a joint which is less stiff after the neural arch has been cut

The stiffness of the intact joints varied between 18 8 kN/cm (L5 S1, specimen 53) and 71 1 kN/cm (L2-L3, specimen 22) The stiffness will depend, *inter alia*, on the thickness of the intervertebral disc (L2-L3 is usually thinner than L5-S1) However, even the highest value of stiffness does not represent the value which would be obtained at very high loads (7–9 kN in flexed posture) when the disc is highly compressed and the end plates of the vertebral bodies are brought closer to each other In other words, the stiffness of the joint varies with the compressive load, although in the range of loads in these experiments there is a long linear portion

As to intervertebral level, all of the L5-S1 joints tested fall into group 1 and five out of six L4-L5 joints fall into group 2. There is no clear variation with age or sex

For four subjects it was possible to test joints at two levels (Table 1) and in every case both joints for each subject fell into the same group (three in group 1 and one in group 2)

DISCUSSION

The maximum value of stiffness recorded in these tests was 71 1 kN/cm Let us compar... this value with the calculated value for th... compressive stiffness of the neural arch, whe... subjected to a force along the line of th... neural lamina

Although the neural lamina is an irregular... shaped structure to provide an approxi...

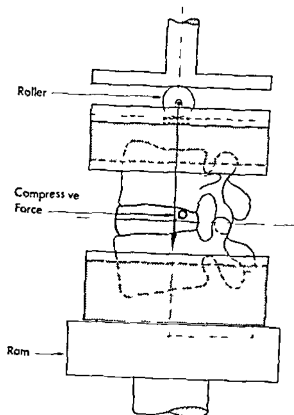


Figure 1 The arrangement of the apparatus for applying a pure compressive force (F_c) to a lumbar intervertebral joint

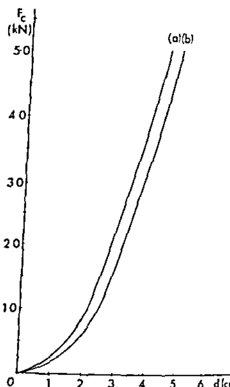


Figure 2 Typical result showing the deformation characteristics of a lumbar vertebral joint in group 1 In this group stiffness remained the same after the neural had been cut

load cell while the base unit held a hydraulic actuator and a displacement transducer

The following two experiments were then performed

Experiment 1

The force/deformation characteristics of the intervertebral joint when subjected to a force perpendicular to the plane midway through the disc were determined. This was achieved by applying forces of known magnitude and direction to the joint through a roller (Figure 1) The roller was free to rotate but its axis was fixed. It was placed at the top of the upper container with its centre lying on the line between the point of application of the force and the centre of rotation of the joint The position of the roller was located by trial and error, a small compressive force (up to 50 N) was applied at each position until it did not cause any tilting of the upper vertebra The outputs from the load cell and displacement transducer were fed to the X-Y plotter which plotted the magnitude of the applied compres force F and the corresponding vertical displ ment d (Figures 2 and 3 graphs (a))

Experiment 2

The neural arch on the upper vertebra was with a chisel through the partes interarticul and Experiment 1 was repeated, giv force/deformation characteristics of the int vertebral joint without any contribution from neural arch (Figures 2 and 3 graphs (b)). should be noted that the joint was loaded slov and allowed to recover before the second expe ment By doing so the amount of resid deformation, after the first experiment was ke to a minimum

After the tests the discs were examin macroscopically for the degree of degeneratio Only results for normal discs and those in whic the lack of a clear boundary between the annul fibrosus and the nucleus pulposus was the onl evidence of degeneration were collected

REFERENCES

Cyron B M (1977) Mechanical factors in the etiology of spondylolysis. Ph.D Thesis. The Polytechnic of Central London

Cyron, B M & Hutton, W C. Variations in the amount and distribution of cortical bone across the partes interarticulares of L5, a predisposing factor in spondylolysis. (Submitted for publication)

Cyron B M & Hutton, W C (1978) The fatigue strength of the lumbar neural arch in spondylolysis. *J Bone Jt Surg* 60-B, 234–238

Evans, F G (1973) *Mechanical properties of bone* Charles C Thomas Springfield

Hutton, W C, Stott, J R R & Cyron, B M (1977) Is spondylolysis a fatigue fracture? *Spine* **2**, 202–209

Nathan, H (1959) Spondylolysis *J Bone Jt Surg* **41-A**, 303–320

Newman, P H (1963) The etiology of spondylolisthesis. *J Bone Jt Surg* 45-B, 39–59

Wiltse, L L, Widell, E H & Jackson, D W (1975) Fatigue fracture, the basic lesion in isthmic spondylolisthesis *J Bone Jt Surg* **57-A**, 17–22

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tion of its stiffness we can assume it to be a tube of cross-sectional area twice that of each pars interarticularis (A force acting along the neural laminae would also produce shear across the partes interarticulares although we will neglect this for a first approximation)

The cross-sectional area at the partes interarticulares is about 1 5 cm², considering both partes (Cyron & Hutton submitted for publication) The length from the tip of the inferior process to the base of the pedicle is about 2 cm, and the modulus of elasticity of cortical bone, when subjected to compression, has not been found to be less than 300 kN/cm² (Evans 1973), therefore the stiffness of the neural laminae is at least 225 kN/cm [(300 × 1 5/2)] Now the greatest change in stiffness of a joint after cutting the neural arch is 16 5 kN/cm (34 9 – 18 4, specimen 35) and this value is over ten times lower than the lowest approximation for the sitffness of the neural laminae The suggestion that the comprehensive force on the L5-S1 joint is transmitted for the most part through the neural arch is not supported by our results.

It could still be argued that the pincer-like process may be due to rubbing on the upper and lower surfaces of the L5 neural laminae This would require the neural laminae to be in close proximity to the tips of the inferior and superior processes of adjacent vertebrae Under the maximum load in these experiments it would be expected that contact would be made and the graphs would change in slope when the stiff neural arch came to bear This did not occur in any of our joints although our sample may have been too small

However, it is possible that under long periods of sustained activity the intervertebral disc may creep and thus narrow, bringing adjacent neural arches closer together This would suggest that a narrowing of the disc, as may occur in disc prolapse, would correlate with an increase in spondylolysis. There is no evidence to date of this

In hyperextension the centre of rotation of the intervertebral joint lies in the anterior half of the disc and it is possible that contact between the tips of the inferior articular process of L4 and the neural laminae of L could be made before the spinous process came to bear If heavy weights were then carried while in this posture the intervertebral disc may narrow and allow the compressive force to be transmitted through the arches. This, however, is not likely to be a common cause for spondylolysis when we consider the high incidence of pars interarticularis defects in soldiers walking in the partially flexed posture with a pack on their back (Newman 1963) In addition the neural arch has been shown to be vulnerable to a cyclic force applied to the inferior articular facets (Cyron & Hutton 1978) and mechanical fatigue seems the most common mode of failure

The question remains why do some of the joints decrease in stiffness after the neural arch has been cut? Consider the magnitude of the change in stiffness for group 2, the values recorded are compatible with the stiffness of soft tissue, the capsular ligaments offer resistance to tension and the inter spinous ligament resistance to compression This may be an individual variation, specimen 35 shows the same characteristics at two levels.

Conclusion

The results of these experiments suggest that, although the posterior elements can transmit compressive force across the intervertebral joint, there is no bony contact between the downward projecting tips of the inferior articular processes and the laminae of the vertebrae below This mechanism is therefore not the usual factor in the aetiology of spondylolysis

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e 1 The different kinds of underside lesions Both sides of each meniscus are shown with the mor part upwards The undersides are to the right Marks from Martins forceps occur in the frontal of the menisci

sci and in two lateral menisci
shows that the posterior part of the underside of the meniscus is completely crushed This type of n was found in 10 menisci all medial

let handle lesions and 23 peripheral s, five with a transverse rupture)
gure 1 shows the different kinds of rside lesions A and B lesions were found 8 patients with a mean age of 40 1 years

C lesions in 8 patients, mean age 32 6 years
D lesions in 10 patients, mean
Patients with underside les
buted more equally in the
(Figure 2) than patients

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UNDERSIDE LESIONS OF THE MENISCUS

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A total of 180 meniscectomies were performed with special attentio lesions located only on the underside of the menisci Thirty six les ons per cent) were found with this location all in the posterior part of menisci Half of these were atypical horizontal cleavage les ons

The clinical features of these lesions were compared with no meniscal lesions and no differences could be demonstrated The subje results after meniscectomy for 35 underside lesions were 94 per cent or excellent after an average follow up period of 22 3 months.

Meniscectomy is the treatment of choice for these lesions. It is em sized that careful examination of the underside of the meniscus is neces if a patient presents a clinical picture of meniscal lesion and no other les can be found

Key words knee joint injury, meniscus lesions semilunar cartilage in pathology trauma knee joint

Accepted 21 iii.78

The anatomy of the knee makes it difficult to recognize lesions in the posterior part of the meniscus (Henderson 1930 Platt 1930 Slocum & Moore 1943, Palmer 1949, Lescoeur 1969, Smillie 1975)

Underside lesions are always found in the posterior segment of the meniscus and are difficult to diagnose They are distinguished from other lesions by not penetrating the upper surface of the meniscal substance

It is not known whether the symptomatology of these lesions is different from other lesions. Underside lesions are not given much attention in the literature and this investigation was undertaken to clarify the incidence of underside lesions and to compare their symptoms with those in other lesions of the menisci

PATIENTS AND METHODS

The material comprises 180 meniscal lesions in 172 patients (63 women 109 men) operated upon in a 3 year period All the meniscectom es performed with special attention to unde lesions. The diagnosis was made by ca examination of the underside of the meniscus a nerve hook. If other lesions were found in meniscus the patient was excluded from underside lesion group This group was comp with the rest of the patients with other kinc meniscal lesions. The patients with unde lesions were examined after a period of 8 mo to 3½ years and the results were analysed.

RESULTS AND FINDINGS

Thirty-six underside lesions were diagn among 180 meniscectomies 30 of t lesions (83 per cent) were in the me meniscus, and 14 (39 per cent) were foun women

In 144 ordinary lesions 97 (67 per c were in the medial meniscus, and 65 (45 cent) were found in women (There were lesions of both the anterior and the poste horn, 45 posterior horn, 10 anterior horn

Table 2 Objective symptoms

	Underside lesions	Other lesions
Direct tenderness at the line of the joint	34/36	129/144
Rotational tenderness at the line of the joint	26/36	86/144
Clicking or snapping felt or heard during examination	12/36	92/144
Limitation of extension	9/36	44/144
No findings at the time of operation	0/36	7/144

Table 3 Duration of symptoms before operation

	Underside lesions	Other lesions
Less than 1 month	6/36	35/144
1 month to 1 year	24/36	71/144
More than 1 year	6/36	38/144

Table 4 Percentage of the various pathological findings in the knees (at meniscectomy)

	36 Underside lesions	144 Other lesions
Lesions of the ligaments	16	14
Osteochondritis or damaged condylar cartilage	19	23
Osteoarthrosis	11	14
Chondromalacia of patella	16	14
Synovial effusion or irritation	44	47
Loose bodies	8	6
[illegible]	8	[illegible]

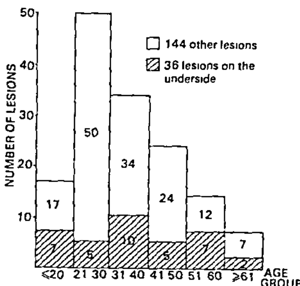


Figure 2 Age distribution

Forty-seven per cent of the patients over 50 years of age had underside lesions.

The symptoms are shown in Tables 1 and 2 Patients with underside lesions more often presented with periodical symptoms The period of time before surgery is shown in Table 3 The percentage of other abnormal findings (Table 4) in the knees is the same in both groups except as regards meniscal cysts, these occurred two to three times more often in patients with underside lesions

The subjective results are shown in Table 5 Fifty-seven per cent (20) had no complaints and were able to perform all previous activities even sport In 37 per cent (13) the results were good The patients felt discomfort after hard or long lasting physical strain or during changes in the weather Six per cent (2) of the patients did not notice ar improvement after meniscectomy

One of these patients, a 49 year-old mal had arthrosis in the knee and a Benjami osteotomy was performed later The othe patient was a 29-year-old male in whom large osteochondritic defect was found on th femoral condyle Later a hemialloplasty wa performed

From Table 5 it can be seen that six of the patients with residual discomfort had either patellar chondromalacia or disease in the condylar cartilage Five patients with the same findings obtained excellent subjective results and so did seven patients with either arthrosis or lesions of the ligaments. Of the six patients with a second meniscectomy on the other side of the knee, three had sustained a new trauma

DISCUSSION

Noble (1977) found, in 200 autopsies, nearly 20 per cent with meniscal lesions. The lesions were all horizontal cleavages, which probably had not given rise to any symptoms. Smillie (1977) states that cleavage lesions in general are more frequent now than previously and they occur in an older age group He demonstrates that some of these lesions are the result of degenerative changes in the substance of the meniscus and that they will often start on the inferior surface of the meniscus

Careful examination of the inferior surface

Table 1 Subjective symptoms

	Underside lesions	Other lesions
Locking	14/36	64/144
Intermittent symptoms pains, click, giving way	21/36	67/144
Constant pains	9/36	61/144
Constant pains with periods of worsening	6/36	16/144

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FORMATION OF NEW MENISCI AFTER POLYCENTRIC KNEE ARTHROPLASTY

Report of Four Cases, One with a Bucket Handle Tear

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This paper presents four patients with polycentric artificial knee joints in whom reoperation revealed new menisci interposed between the artificial

and the reoperations were performed because of trauma in one patient because of femoro-patellar problems in one knee and for conversion of a hemi arthroplasty to an arthroplasty including all the compartments of the knee joint in two patients.

Key words Marmor knee, meniscus tear, polycentric knee arthroplasty, meniscus regeneration, St Georg knee

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Regeneration, at least to some extent, of the knee meniscus after surgical removal is an accepted phenomenon (Smillie 1963, 1974) Excision of an injured meniscus from an otherwise normal knee joint will generally be subtotal A capsular brim will be left, from which the regeneration can proceed In knees subjected to polycentric, unicondylar arthroplasty because of degenerative or rheumatoid arthritis, the menisci are often absent at the time of operation If they are still present they are radically excised to allow the tibial prosthetic component to be put into place

Since June 1976 we have reoperated on four patients who had undergone a polycentric knee arthroplasty Two of the arthroplasties were of the St Georg "Schlitten" type (Engelbrecht 1971) and two of the Marmor type (Marmor 1973) The reasons for the reoperations were traumatic injuries to the joints or conversion of a unicompartment to a duocompartment arthroplasty All four knees showed meniscus-like formations between the artificial surfaces. One of the menisci had a bucket handle tear This meniscus was excised and could thus be examined histologically

CASE REPORTS

Case 1 D A a 55 year-old woman had had severe rheumatoid arthritis since 1961, with multiple involvement of the joints. She had had no steroid therapy Her left knee was unstable, with poor function, and caused severe pain. Because of this she was operated on in December 1975 At operation a fairly inactive synovitis and heavy destruction of the joint surfaces were found, both menisci were completely eroded Marmor arthroplasty including both partments was performed. quickly gained good mobility of the able to walk well, and had no walking However there was the femoro-patellar joint

Table 5 Subjective results after meniscectomy of 35 underside lesions The main findings during th operation and the later operations on the knees are shown in each group

		Lesions of cruciate ligaments	Chondromalacia of patella	Osteochondritis or cartilage damage	Arthrosis	Later operations on the knee
Excellent	20 (57 per cent)	4	2	3	3 (1 severe)	3 (2 meniscectomies 1 Hauser operation)
Good	13 (37 per cent)	1	3	3		4 (meniscectomies, one also synovectomy)
Unchanged	2 (6 per cent)	1	1	1	1	2 (1 Benjamin operatio 1 hemialloplasty)

of the meniscus with a nerve hook revealed that one fifth of the meniscal lesions were located here, always in the posterior part of the meniscus Half of these lesions were obviously atypical horizontal cleavage lesions and the other half might have developed from similar lesions The symptoms in patients with underside lesions were the same as the symptoms in patients with other well known types of meniscal lesions After meniscectomy for underside lesions, 94 per cent achieved excellent or good results This is in agreement with the results from the literature, i e good or excellent results in 65 to 100 per cent of the cases (Saugmann-Jensen 1963) The results of this follow-up must be [illegible] d with reservation as the observa[illegible] i period is only 22 3 months on an average

Underside lesions may be symptomless, but a patient with a clinical picture of meniscal lesion must be carefully examined for underside lesions, if no other lesions are found in the meniscus In such cases underside lesions are an indication for removal of the meniscus Whether the examination for underside lesions can be performed as reliabl by arthroscopy as by arthrotomy has not yt been clarified

REFERENCES

Henderson, M S (1930) Injuries to the semiluna cartilages of the knee joint *Surg Gynec Obstet* 91, 720–726

Lescoeur, J E (1969) *La chirurgie du ménisque e les problèmes posés par la corne postérieure Bulletin Soc Chirurgiens Paris* 59 236–241

Noble, J (1977) Lesions of the menisci Autops incidence in adults less than fifty five years old *J Bone Jt Surg* 59 A, 480–483

Palmer, I (1949) On injuries to the posterior hon of the medial semilunar cartilage *Acta chir scand* 98 523–529

Platt, H (1930) Lesions of the semilunar cartilage of the knee joint *Acta chir scand* 67, 654–66!

Saugmann-Jensen, J (1963) Meniscus-injuries c the knee joint Thesis. Copenhagen

Slocum, D B & Moore D E (1943) Posterio horn lesions in meniscal injuries *Surg Gynec Obstet* 77, 87–90

Smillie, I S (1975) *Injuries of the knee joint* 4t ed revised reprint

Smillie, I S (1977) Degenerative lesions of th menisci (Proceedings) *J Bone Jt Surg* 59-B 100–101

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methods Sections were stained according to van Gieson and with haematoxylin and eosin The light microscopical findings were those of a fibrocartilage built up of cartilage cells with a scanty matrix surrounded by a dense connective tissue with abundant collagen in parallel, wavy bundles (Figure 3) The structure was covered by a loose synovial membrane (Figure 4) and the morphology was thus almost indistinguishable from a normal meniscus

Case 3 P P, a 70 year old man, sustained in the 1960's an open tibial fracture of the right leg, which had healed after several operations Because of an idiopathic osteoarthritis in the right knee, a hemi arthroplasty including the lateral compartment, was performed in March 1974 A St Georg "Schlitten" prosthesis was used Unfortunately a slight overcorrection into varus position was made, and pain developed from the medial compartment of the joint The arthroplasty was therefore complemented with a Marmor prosthesis in the medial compartment 3 years later A meniscus-like formation was found between the surfaces of the St Georg prosthesis, which seemed to fit well and to be quite firmly in position The meniscus showed no signs of injury and was left in place The function of the knee after the additional arthroplasty was excellent

Case 4 B A, a 50-year-old man had had rheumatoid arthritis since 1969 Multiple joint involvement had resulted in general functional impairment, but he was still working in a workshop Because of severe pain and derangement of the right knee, a polycentric unicondylar arthroplasty, including both compartments of the knee joint, was carried out in 1976 A Marmor prosthesis was used Postoperatively the patient was completely free of pain and the knee function was excellent Six months later a Charnley arthroplasty was performed in the right hip, and the result of this operation with regard to function and freedom from pain was also excellent Eighteen months after the knee operation a traumatic distortion of the right arthroplastic knee occurred and there were clinical signs of a loose body (bone cement) An arthrotomy was therefore carried out and the loose body removed At the arthrotomy it was noted that new menisci had formed between the artificial joint surfaces They appeared healthy with no signs of injury, and were left in place Postoperatively, good joint function was regained

COMMENTS

The finding of new menisci between the artificial surfaces in polycentric knee arthroplasties indicates a strong capacity for regeneration from the fibrous capsule

The healthy appearance of the meniscus in all but one of the four cases reported here hopefully indicates that the function of the artificial knee resembles that of the normal knee joint In polycentric artificial knees with unicondylar components, such as the Marmor or the St Georg "Schlitten" prosthesis, the possibility of an injury to a newly formed meniscus should be kept in mind if, after a period of good function, signs of mechanical trouble appear and there are no roentgenological indications of prosthetic problems.

REFERENCES

[illegible]
edition, pp 64–69, Churchill, Livingstone Edinburgh and London
Smillie, I S (1974) *Diseases of the knee joint*, p 323 Churchill, Livingstone, Edinburgh and London

Correspondence to Anders Wigren, M D, Department of Orthopaedic Surgery, University Hospital, 750 14 Uppsala, Sweden

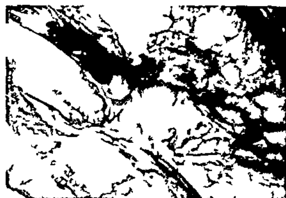


Figure 1 Anterior view of the arthrotomized knee joint showing the St Georg prosthesis and the bucket handle tear of the new meniscus

Figure 2 The excised meniscus

roentgenologically conflict was found between the patella and the lateral femoral prosthesis An arthrotomy was therefore carried out 6 months after the primary operation and a hemi patellectomy was performed It was noted that there were meniscus like formations between the joint surfaces in both compartments. The newly formed menisci appeared almost like normal ones After the reoperation her function was excellent and the knee caused no pain. She has now been followed up for 2 years and in that time has had no trouble with the treated knee

Case 2 B M a 62 year-old woman, sustained an injury to her left knee in 1971 with a depression fracture of the medial tibial condyle This was treated by open reduction and fixation with screws. Later on an osteotomy had to be performed to compensate for an unacceptable joint position. Increasing pain on weight bearing followed and in 1973 a unicondylar St Georg prosthesis was inserted in the medial compartment of the left knee joint. Some stability remained and after a year or two began to have pain in the knee localized over lateral compartment There was no locking of knee joint In February 1977 a further opera was performed, at which the knee prosthesis complemented with a Marmor prosthesis in lateral compartment The first St Georg p thesis was found to be sitting firmly in posit with no signs of wear A new meniscus, wi bucket handle tear (Figure 1) had formed betw the artificial joint surfaces of the St. G prosthesis and was excised (Figure Postoperatively the patient quickly gained g walking ability and an almost normal range movement and had hardly any pain in the k The excised meniscus was examined h logically

Histopathology The removed material was fi in 4 per cent buffered formaldehyde dehydr and embedded in wax according to rou



Figure 3 Light microscopy of the new meniscus showing a fibrocartilage built up of cartilage cells surrounded by a dense connective tissue with abundant collagen in parallel wavy bundles



Figure 4 A loose synovial membrane covered structure the morphology of which was very m like that of a normal meniscus



Figure 1A Antero-posterior roentenogram, showing abnormal prominence of the fibular head



B In the lateral view, the head of the fibula is seen projecting anteriorly

He presents 43 cases 29 antero-lateral luxations, three postero-medial, one superior luxation and finally 10 cases of subluxation The latter condition is described as an excessive symptomatic antero-posterior movement without any actual luxation As is demonstrated in this series antero-lateral luxation is the most frequent type It was shown that the postero-medial type involves an increased risk of nerve damage and that the proximal or superior type is unusual and has not been observed as an isolated lesion but always in connection with a fracture According to Ogden most antero-lateral luxations arise during participation in sport, especially after violent twisting movements The injury may however arise from direct trauma.

The symptoms consist primarily of pain and tenderness in the region of the head of the fibula There is often an extension defect and the patient is unable to stand on the leg Diagnosis can usually be made clinically, but an X-ray examination of both knees is required for verification The lesion can easily be overlooked if the X-ray picture is not optimal Treatment is simple and as in the case described here consists of closed replacement of the head of the fibula Exp
with this case suggests that

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ISOLATED TRAUMATIC LUXATION OF THE HEAD OF THE FIBULA

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Isolated traumatic luxation of the head of the fibula is a rare lesion. Th
lesion is discussed against the background of a diagnosed and treated case

Key words dislocation, fibula

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Traumatic luxation of the head of the fibula is a rare lesion, seldom reported in Scandinavian medical literature (Christensen 1966, Gudbjerg 1970, Bacieu et al 1974).

In major radiological textbooks the luxation is described briefly (Schinz et al 1952) whereas no reference to the lesion is to be found in ordinary textbooks of surgery

CASE REPORT

An 18-year-old girl with no previous history of knee injury fell while playing handball She hit her left knee and felt a "click" On examination the knee was fixed in 140° of flexion due to pain, and a painful swelling was seen on the lateral side of the knee joint. There was no haemarthron or instability of the joint and no sign of peroneus paralysis. X-ray examination of the knee (Figure 1A and 1B) showed an antero-lateral luxation of the head of the fibula but no fracture A closed reduction was carried out with local analgesia An audible crack accompanied the replacement of the bone X ray examinatio showed that the luxation had been reduced. Ful mobilization with support was allowed im mediately

X-ray examination 6 months later showe normal conditions (Figure 2A and 2B). The patien was symptom free and the clinical examinatio normal

DISCUSSION

The lesion was first described by Nélaton in 1874 In 1925 Lyle collected 36 cases from the medical literature and described two new ones Of these 36 cases, 20 were antero-lateral luxations, 12 were posterior and 4 superior More recently further cases have been documented in the literature (Stratford 1959, Harrison & Hindenach 1959, Christensen 1966, Gudbjerg 1970)

Ogden's material from 1974 is the largest.

[Ac]ta orthop scand 49, 621–626, 1978

[IN]STABILITY OF THE PROXIMAL [TI]BIO-FIBULAR JOINT

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The proximal tibio-fibular joint consists of a joint cavity surrounded by a joint capsule (diarthrosis) forming a rather rigid joint In patients who complain of pain and instability in the knee, the cause may sometimes be found in laxity of the proximal tibio-fibular joint In these cases the abnormal movements of the fibular head are palpable and visible and can be demonstrated on X-ray films

The disease is not well known and is often overlooked It can be differentiated by palpating the fibular head In two patients the pain and disability were so severe that fusion of the proximal tibio-fibular joint was undertaken This treatment seems to have been successful

Key words arthrodesis, head of fibula, instability, proximal tibio-fibular joint

Accepted 25 iii 78

[Ins]tability of the proximal tibio-fibular joint

The proximal tibio-fibular joint consists of [the] articulating surfaces of the upper end of [the] fibular head and the lateral condyle of [the] tibia, which are covered with hyaline [car]tilage The capsule is reinforced anteriorly [and] posteriorly by two ligaments Radio[gra]phically the joint space is visible only in [obl]ique projections

[I]n the orthopaedic and [...] [lite]rature, dislocation of the fi[...] [mo]stly described in combin[ation with fra]cture of the tibia and the [...] [i]n traumatic disorders of [...]

[Sy]mptomatology

Recurrent dislocation [...] [...]ular joint is found [...] [so]metimes in [...] [...] history of [...] [...]sult in [...] way", "My knee locks" and "There is a click somewhere in the joint" Diffuse pain, not only in the unstable joint, but sometimes on the medial side of the knee is recorded, suggesting a meniscus lesion However there is no wasting of the quadriceps and no swelling

Because this lesion is not found in older patients there seems to be a tendency towards spontaneous improvement

[...]igns

[...] of the fibular head is best [...]th the patient in the supine [...] is flexed to 90°, with the [...] especially the biceps femoris [...]s unstable the fibular head [...] mb and index finger can [...] and laterally On releas[ing ...] a click to its original [...] can be to the extent [...]ly visible (Figure 1)



Figure 2A Antero-posterior view, normal position of the head

B In the lateral view, normal position

REFERENCES

Bacieu, Cl C, Tudor, Al & Olaru, I (1974) Recurrent luxation of the superior tibio-fibular joint in the adult *Acta orthop scand* **45**, 772–777

Christensen, S (1966) Dislocation of the upper end of the fibula *Acta orthop scand* **37**, 107–109

Gudbjerg, L P (1970) Isolated traumatic luxation of caput fibulae *Ugeskr Laeg* **132**, 1726–1728

Harrison, R & Hindenach J C R (1959) Dislocation of the upper end of the fibulae *J Bone Jt Surg* 41-B 114–120

Lyle, H H M (1925) Traumatic luxation of the head of the fibula *Ann Surg* **82**, 635–639

Nélaton, A (1874) *Eléments de pathologie chirurgicale*, 2nd ed Vol 3 p 286 Librai Germer Baillière, Paris.

Ogden, J A. (1974) Subluxation and dislocation the proximal tibiofibular joint *J Bone Surg* 56-A, 145–154

Ogden, J A (1974) Subluxation of the proxir tibio-fibular joint *Clin Orthop* **101**, 192–1

Schinz, H R, Baensch, W E, Friedl E & Uehlinger, E (1952) *Lehrbuch* ... 1280 ...

Str ...

41-B, 120–121

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-oneal nerve and its branches are kept aside -ully The proximal tibio-fibular joint is -sed anteriorly and the joint cartilage -oved with small chisels The next step in - operation is to *fix the roughened joint* -faces to each other under compression -h two *selftapping* spongiosa screws To -ge defects in the arthrodesed joint, -ngiosa chips can be taken from the tibial -d through the same incision A below-knee -ular plaster is applied on the 10th -stoperative day after removal of the -ches. This plaster is worn for 5 weeks -l weight bearing is permitted 8 weeks -r the operation

-SE REPORT

-this report six cases have been collected -r data are given in Table 1 One of the -ents (case 3) is reported in detail

Case 3

A girl 14 years old was referred in November 1969 with a 6-month history of weakness in both knees. She experienced pain during sporting activities and she had trouble going upstairs. Four months prior to the onset of knee symptoms, the *right knee had suffered a minor injury but she* could recall no further trauma

On examination the girl was of the asthenic type The knees were not swollen and the mobility was unimpaired The collateral and cruciate ligaments were intact Posterior pressure on the fibular head caused it to dislocate more than 1 cm anteriorly (Figure 3)

Analgetics did not relieve the disability In the course of a few months her knees grew worse preventing her going up and down stairs and attending school.

Because the only abnormality was the instability of the fibular head it was decided to arthrodese the unstable upper tibio-fibular joint The operation was done in March 1970 on both knees according to the method described pre-

-le 1 Patients with laxity of the proximal tibio-fibular joint Cases 1 5 have bilateral symptoms, case 6 has unilateral symptoms of traumatic origin

-ent	History	Anamnesis Complaints	Handicap	Treatment
-5 years	trauma	click in both knees, pain absent	—	—
17 years	trauma	no symptoms, no pain	no handicap participates in several sports	—
14 years	slight trauma, right knee	bilateral knee troubles, gradually growing worse	unable to go up and down stairs and to take part in sport	arthrodesis proximal tibio-fibular joints, complete recovery
15 years	bilateral knee trouble of 2 years duration	giving way of both knees	unable to take part in sport except swimming	arthrodesis proximal tibio-fibular joint complete recovery
19 years	bilateral knee troubles of 4 years duration Visited several doctors	click in both knees, no locking	unable to take part in sport (was an enthusiastic sportsman)	—
18 years	2 years previously trauma to left knee with multiple skin wounds, 1 year previously lateral meniscectomy	click in lateral compartment of the left knee	unable to take part in sport	in the past a meniscectomy without relief



Figure 1 Antero lateral dislocation of the fibular head, induced by manual pressure, in a 19-year old boy (case 5)

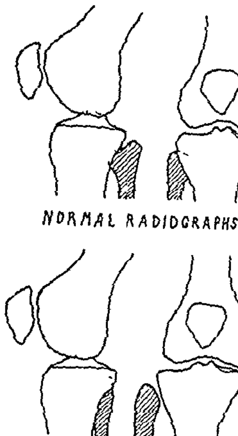


Figure 2 Antero-lateral displacement of t fibular head in A P and lateral radiographs

This examination is not painful and can be done in a relaxed patient without any form of anaesthesia

Radiological appearances

The antero-posterior radiographs, in the case of a dislocated tibio-fibular joint, show a lateral dislocation of the fibular head, the lateral radiograph reveals an anterior displacement (Figure 2)

Treatment

The hypermobile tibio-fibular joint occurs with different degrees of laxity In mild cases the patient is not always aware of the disorder and no treatment needs to be given In cases giving rise to trouble only during sporting activities, a supportive bandage ca be used Because the symptoms tend t disappear spontaneously, operative treatment is seldom necessary

However the clinical picture is rather similar to that of a meniscus lesion and sometimes by error a meniscectomy is carried out (case 6). In a few cases the instability may even make stair climbing difficult. In these patients operative treatment should be considered Operative fusion of the proximal tibio-fibular joint was carried out in two of the patients described

Surgical technique

In a bloodless extremity, the fibular head is freed through a 7 cm longitudinal lateral incision After careful preparation the

l nerve and its branches are kept aside · The proximal tibio-fibular joint is anteriorly and the joint cartilage with small chisels The next step in ration is to fix the roughened joint s to each other under compression wo selftapping spongiosa screws To defects in the arthrodesed joint, osa chips can be taken from the tibial hrough the same incision A below knee r plaster is applied on the 10th erative day after removal of the This plaster is worn for 5 weeks weight bearing is permitted 8 weeks the operation

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superior tibio-fibular joint and described two adolescents suffering from this disorder The disability in these cases was to such a mild degree that surgery could be avoided It is evident that the symptoms in acute traumatic dislocation of the proximal tibio-fibular joint catch the attention of the clinicians much more than the rather vague complaints in recurrent (sub)luxation of the joint This is the reason why this disorder may be easily overlooked and seldom is reported in the literature

Ogden (1974) studied 43 cases of subluxation and dislocation of the proximal fibula Six of them had chronic instability (subluxation) They were aged from 8 to 14 years In his opinion idiopathic subluxation in the young patient should not be treated surgically, as it appears to be a self-limiting condition He considers that when necessary, resection of the proximal fibula is preferable to arthrodesis of the proximal tibio-fibular joint, in order to preserve the function of the ankle joint

The cases in this paper have all been observed within a period of 5 years This suggests that the disorder under discussion is not so rare Early diagnosis gives an understanding of the dysfunction of the knee and can avoid unnecessary and possibly inappropriate surgery (case 6)

RFFERENCES

Bohler, L (1938) *Die Technik d Knochenbruchbehandlung* Wilhelm Maudr Vienna

Campbell's Operative Orthopaedics (1956)

De

with peroneal nerve palsy *J Bone Jt Su* 40 A 1146–1148

Hohmann G, Hackenbroch M & Lindemann, (1961) *Handbuch der Orthopaedie* Ge Thieme Verlag Stuttgart

Harrison R & Hindenach J G R (19 Dislocation of the upper end of the fibula *Bone Jt Surg* 41 B 114–120

Ogden J A (1974) Subluxation of the proxi tibio-fibular joint *Clin Orthop* 101, 192 1

Owen R (1968) Recurrent dislocation of superior tibio-fibular joint *J Bone Jt Su* 50 B 342–345

Palma A F de (1954) *Diseases of the kn* Lippincott Company Philadelphia

Palma A F de (1959) *The management fractures and dislocations* Saunders Compa Philadelphia and London

of the knee joint

superior tibio-fibular jo

41 B 120–121

Vitt R J (1948) Dislocation of the head of fibula *J Bone Jt Surg* 30 A 1012–1013

Watson Jones R (1960) *Fractures and jo injuries* Livingstone London

Correspondence to S Sijbrandij Catharijnesingel 101 Utrecht, The Netherlands.

Provided there had been no previous loss of bone substance at the metatarsophalangeal joint a hallux valgus deformity with or without rigidus did not adversely affect the incidence of union after cone arthrodesis In this survey ten such toes united without complications. Their preoperative valgus angles between 25 and 48 degrees with an average of 33 degrees

Movement at the arthrodesis site prior to radiological union

Six arthrodesed toes had to be excluded due to insufficient data Out of the remaining 77 toes comparative values for the Valgus Angle A were available in 76 and for the Dorsiflexion Angle B in 22 toes

Out of the 77 toes where one or both of these measurements were available there was evidence that movement had occurred between the proximal phalanx and the first metatarsal in three In two toes the movement had taken place at a stress fracture of the metatarsal and not at the arthrodesis site The third patient was the only one where movement was shown to have occurred at the arthrodesis itself In this patient no additional wire or staple fixation had been used

In the other three toes where stabilization had not been used uncomplicated union occurred without evidence of change in the operative position.

In none of the 29 toes examined clinically was there any evidence of a significant rotation deformity of the great toe

Wire and staple fixation

A wire circle was used for stabilization in 79 toes This had disrupted due to a fatigue fracture of the metal in the two ununited arthrodeses and in the patient with an ununited stress fracture across the base of the cone (Figure 2B) In the remaining 76 arthrodesed toes the circle was intact

In no patient did the metal cause any significant symptoms or have to be removed

Complications

(1) Stress fracture of the metatarsal occurred in two toes One patient had a stiff ankle from a previous injury and sustained a

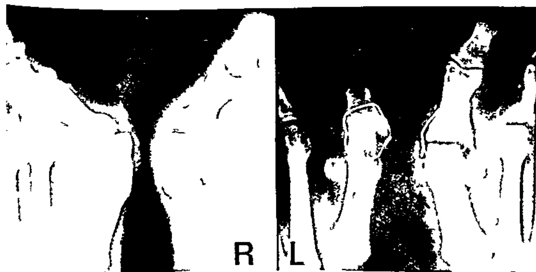


Figure 2 Radiographs showing a stress fracture through the base of the right cone in a patient previously undergone bilateral exostectomies A Before arthrodesis B 2 years after arthrodesis The left side has united.

stress fracture of the first metatarsal neck 3 years after arthrodesis

The second patient sustained a stress fracture through the base of the cone 12 weeks after surgery Previously she had undergone bilateral exostectomies thus narrowing and weakening the metatarsal heads. Both arthrodeses united, but the stress fracture went on to non-union (Figures 2A and B)

(2) There was one patient with transient superficial sepsis of the wound No deep sepsis was encountered

No other complications of the operation itself were noted

DISCUSSION

In patients who had undergone no previous surgery to the metatarsophalangeal joint, cone arthrodesis resulted in a union rate of 100 per cent This probably relates to the ideal conditions for arthrodesis that can be achieved with this technique A perfect driving fit is obtained between the proximal peg and distal cone thus bringing the cancellous surfaces into intimate contact

These ideal conditions are much more difficult to achieve where bone has been removed at previous surgery Such a procedure inevitably weakens and narrows the cone ailable for arthrodesis Following previous ple metatarsal exostectomy two toes failed unite and one sustained a stress fracture across the base of the cone However, uncomplicated bony union occurred in four toes after simple exostectomy four after a previous Mayo procedure and one after a Keller operation Where previous surgery has resulted in loss of bone substance at the metatarsophalangeal joint cone arthrodesis is probably the best method of obtaining bony union

In this retrospective survey clinical assessment of rotation and the comparative values for valgus and dorsiflexion angles were not available in all patients. However all three criteria were recorded in each of 18 toes and showed no evidence of a change in the operative position up to the time of bony union At least one of the two angles was recorded in 59 arthrodesed toes. A change in the operative position at the time of union occurred in only one of these and in this case no additional stabilization had been used

Although these records are incomplete they can be taken as a strong indication that cone arthrodesis using a wire stabilization technique does maintain the operative position until bone union occurs

Conclusions

(1) Cone arthrodesis of the first metatarsophalangeal joint gave a 100 per cent union rate in patients who had not undergone previous surgery to the joint
(2) A high incidence of union is achieved by this technique even in patients who have lost bony substance from the joint at previous surgical procedures.
(3) There is a strong indication that the technique described, using wire stabilization, does maintain the arthrodesis in the position obtained at operation until bony union occurs

ACKNOWLEDGEMENTS

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REFERENCES

Fitzgerald J A W (1969) A review of long term results of arthrodesis of the first metatarsophalangeal joint *J Bone Jt Surg* 51 B 488–493

Marin G A (1960) Arthrodesis of the first metatarsophalangeal joint for hallux valgus and hallux rigidus *Guy's Hosp Rep* 109, 174–175

Wilson J N (1967) Cone arthrodesis of the first metatarsophalangeal joint *J Bone Jt Surg* 49 B 98–101

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PROCEEDINGS OF THE NORWEGIAN ORTHOPAEDIC ASSOCIATION

EDITOR ARNT JAKOBSEN

Oslo, September 17th, 1977

TRAUMATIC DISLOCATION OF THE HIP JOINT

Astor Reigstad
Ullevål Hospital, Oslo

In the period 1960–1976, 57 posterior dislocations of the hip joint were treated in Ullevål Hospital, Surgical Department 2 The mean age was 31 years, half of the patients were between 15 and 30 years of age, and three-quarters were males.

Traffic accidents caused 66 per cent, and skiing accidents 9 per cent of the dislocations Twenty-five per cent of the patients suffered from other serious injuries, and two of the patients died

Thirty-three per cent had a small, and 11 per cent a large fracture of the acetabulum, 9 per cent had a fracture of the head or shaft of the femur, and compression of the sciatic nerve was seen in 5 per cent.

Seventy-five per cent of the dislocations were reduced within 5 hours after the injury Eighteen per cent had open reduction and/or fixation of the fracture

During the observation time, 11 per cent of the patients developed traumatic arthritis all having had fractures of the acetabulum, and avascular necrosis of the head of the femur was seen in 5 per cent.

FIBROSARCOMA IN THE SHOULDER REGION

Svenn M Syversen
Ullevål Hospital, Oslo

A 33-year-old man had suffered for a period of 6 years from shoulder pain, and had gradually [illegible] fracture Radiological [illegible] tion showed fibrosarcoma.

The patient died 6 months later from pulmonary metastases.

Oslo, October 27th–29th, 1977

TOTAL PROSTHESIS OF THE KNEE JOINT

Cato Hellum
Kronprinsesse Marthas Institutt, Oslo

Since the year 1971 the Guepar prosthesis has been inserted into 40 knees. Thirty-five had rheumatoid arthritis, nine knees had been operated on previously, and eight had ankylosis of the contralateral knee

Technique and aftertreatment (*Acta orthop scand* 47, 579, 1976)

The results were good in 29 cases. There was occasional pain or swelling in three cases and eight were classified as poor Of the eight poor results in one the stem perforated the femur and there was very limited mobility, one had infection and almost complete ankylosis, and two had infection and prosthesis removal. Two other patients with infection were able to walk around during antibiotic treatment with only slight symptoms, but a flare-up occurred if medication was stopped In two cases loosening of the prosthesis occurred

PROSTHESES OF THE KNEE JOINT

Leif Egil Nygaard
Central County Hospital, Fredrikstad

The results in 17 cases of Guepar total prosthesis, and in 10 cases of Marmor modular prosthesis, are reported In one case infection occurred

The total prosthesis is preferred if there is gross destruction, instability and poor mobility The condylar prosthesis is used in knees with less destruction and greater mobility In the latter type better stability can be gained, but the range of motion remains unchanged.

KNEE PROSTHESES IN RHEUMATOID ARTHRITIS

J Teigland
Oslo Sanitetsforening Rheumatism Hospital, Oslo

A follow-up examination in 1977 of 31 McIntosh knee prostheses, inserted in the period from 1968 to 1973, revealed that in 16 of these joints the prosthesis was still in use without any particular subjective inconvenience All had to a greater or lesser extent become embedded in the tibia

In the same period 21 Shier prostheses were inserted, of which 19 still are working well Two have been removed, one because of infection and one on account of severe skin necrosis

From 1973 to 1977, 71 Guepar prostheses have been inserted Sixty-five are working well, one became infected, one loosened and was refixed, and one required re-operation because of pronounced outward rotation of the tibia and patellar dislocation

Since 1974 3 Schlitten and 13 Marmor prostheses have been inserted In one case the prosthesis became embedded in the tibia, and had to be replaced with a Guepar prosthesis The remaining have so far been satisfactory

POLYGLYCOLIC ACID (DEXON®) INTRACUTANEOUS SUTURE IN

[illegible]

cutaneous skin closure with absorbable erials, where stitches do not have to be oved, obviously has some advantages in aediatric surgery It has been found, however, hat intracutaneous closure with Dexon® has given ypertrophic scars

In a comparative study in 37 patients, age range –13 years, half of the wound, or one of the ounds in bilateral operations, was closed with onventional interrupted skin sutures (Supramid®), he other half with intracutaneous suture (Dexon®), 50 wounds with each technique

Inflammatory reactions 14 days after operation were least common after intracutaneous suture At follow-up, mean 14 months after operation, hypertrophic scar formation was found in 71 instances, but no significant difference was found between the two techniques. The scars tended to be broader, but the total cosmetic results to some extent favoured Dexon® intracutaneous suture

TENODESIS FOR CLAW-HAND

Olav Histøl
Kronprinsesse Marthas Institutt, Oslo

Seven patients operated for claw hand *ad modum* Parkes have been followed up The primary cause of the lesions was injury of the ulnar and median nerves.

The grip function of the hand in which the metacarpo-phalangeal joints have a key position, was evaluated Results were good or fair in six patients. One patient who had a poor result showed considerably reduced finger extension function

It is concluded that in Parkes' tenodesis operation for claw hand, good preoperative function of flexion and extension muscles is mandatory

THE ROLE OF THE CORACO-ACROMIAL LIGAMENT IN SHOULDER DISORDERS

A Vebostad
County Hospital, Harstad

The author has made some clinical and peroperative observations indicating that the rotator cuff in some cases of painful arc syndrome impinges on the coraco-acromial ligament as well as on the acromion Support for this observation is found in the literature The ligament, therefore should be sectioned in chronic shoulder disorders, either alone, or most often as part of the operative procedure

Seven out of 21 patients referred for chronic painful arc syndrome, who showed tenderness of the coracoid process, had the ligament sectioned as the only treatment Two patients were relieved of the pain immediately and completely, four were relieved of the discomfort which was localized to the coracoid process although the laterally localized pain continued, and in one patient no effect was observed

SURGICAL TREATMENT OF PARTIAL ACHILLES TENDON RUPTURE

Tor Finn Denstad & Asbjørn Roaas
Martina Hansens Hospital, Sandvika

Partial Achilles tendon ruptures are not uncommon in physically active individuals, in particular middle- and long-distance runners.

Fifty-eight partial tendon ruptures in 54 patients have been treated, during the period 1970–1976, by excision of pathological tissue

side-to-side closure of the tendon defect and immediate postoperative exercises directed by a physiotherapist

All patients returned a questionnaire The result was excellent or good in 52 instances in three of these after re-operation One patient had died from unrelated causes. The remaining five were improved, but the observation time was short

SUPRASCAPULAR NERVE COMPRESSION FOLLOWING FRACTURE OF THE SCAPULA

Ludvig Fjeld Solheim & Asbjørn Roaas
Martina Hansens Hospital, Sandvika

Residual disability following a fracture of the scapula might be due to a lesion of the suprascapular nerve where it passes through the suprascapular notch

A 32 year-old man with a fracture of the notch, and lesion of the suprascapular nerve is reported A nerve decompression operation including a wide resection of the notch, was performed 20 months after the injury, with relief of pain.

The value of X-ray examination, using projections visualizing the suprascapular notch, and a local anaesthetic block at the notch in order to diagnose lesion of the nerve is emphasized

FRACTURE OF THE TALUS IN CHILDREN

Helge Fjermeros
Central Hospital in Kristiansand, Kristiansand

Fractures of the collum tali are of special interest, because this type of fracture often leads to necrosis of the trochlea, and/or development of osteoarthritis in the talo-crural or the subtalar joints. This fracture is only mentioned in the literature 15–20 times in children under 15 years of age

Two cases of severe fracture-dislocation of the collum tali in children, aged 10 and 13 years, were treated at our hospital with open reduction, and non-weight-bearing with the use of crutches for one-and a-half and one year, respectively The fractures have healed, and the children have no discomfort at all, 3–4 years later Radiological examination showed for a time all the signs of necrosis, but later re-vascularisation took place The shape of the talus is fairly well preserved

This good result is attributed to the very long period of non-weight bearing and this is recommended in similar cases

ARE "IMPACTED" FRACTURES OF THE NECK OF THE FEMUR REALLY IMPACTED?

Ulf Slungaard
Aker Hospital, Oslo

During a 5-year period ending June 1977, 117 patients with so-called impacted fractures of the neck of the femur were admitted to Aker Hospital Fifty-eight were treated with primary osteofixation, while 59 were treated conservatively with non-weight-bearing, most often because of minimal dislocation on lateral X rays

Out of 51 of the latter who were followed up, 12 dislocated without a new trauma after an interval of a few days up to 4–5 weeks, i.e., dis-impaction occurred in 20 per cent.

The term "impacted" often seems to be a misnomer, and it is proposed that these fractures be called, e g, fractures of the first degree, or fractures with minimal or moderate dislocation.

OSTEOMYELITIS FOLLOWING FRACTURE SURGERY

Rolf Hagen
Martina Hansens Hospital, Sandvika

During the period 1967–1975 a total of 62 patients with 63 previously operated fractures were treated for osteomyelitis after osteosynthesis. The lower extremities had been fractured in 89 per cent of the cases, and 54 per cent were closed injuries. About half of the patients had been operated within 24 hours after injury, 30 with insertion of plates and 25 with insertion of intramedullary nails or pins, 51 per cent revealed postoperative instability

The treatment consisted mainly of sequestrectomies and saucerizations, supported by 3–12 months Lincomycin® medication. In 30 operations a closed irrigation-suction technique was used, perfusing the wound with a Lincomycin® solution.

The average follow-up was 6.5 years, and the result was judged as good in 74 per cent, fair in 8 per cent, and poor in 18 per cent. The amputation rate was 14 per cent.

Stable implants should not be removed before clinical consolidation has been achieved, while unstable osteosyntheses should be replaced with rigid internal or external Hoffmann fixation. Autologous cancellous bone-grafting of a purulent pseudarthrosis should be postponed until infection has subsided or practically d...

ARTHROSCOPY

Norvald Langeland
Sophies Minde Orthopaedic Hospital, Oslo

Arthroscopy of the knee joint is a valuable method for the examination and diagnosis of

bodies

In most instances the method seems superior to arthrography Photography through the arthroscope is easy, and gives excellent documentation of the findings However, interpretation of arthroscopic findings may be difficult, and special experience is mandatory

The author prefers to use an arthroscope 4 5–5 mm in diameter, and to perform the examination under general anaesthesia

TUBERCULOSIS OF THE KNEE JOINT A 20-YEAR MATERIAL

Asbjørn Roaas
Martina Hansens Hospital Sandvika

Seventy-nine patients with tuberculosis of the knee joint were treated in this hospital during the period 1955–1974 Local symptoms and signs such as pain, swelling, atrophy and reduced mobility were frequent General symptoms were rare Twenty-six patients had had their symptoms for more than 5 years

All, except two, were treated with streptomycin, isoniazid and PAS Thirty patients were operated upon, of these 21 had an arthrodesis performed

Forty-five were traced At follow-up only three plained of pain in their knees, and two of se were able to continue working Eleven of the n-operated patients had almost normal mobility 'eventeen of the patients who had an arthrodesis were completely satisfied There were no recurrences of the tuberculous disease

DIFFERENT WAYS OF TREATING PERTHES' DISEASE

Håvard Bjerkholt, Norvald Langeland & Elling Alvik
Martina Hansens Hospital Sandvika
Sophies Minde Orthopaedic Hospital, Oslo

A comparative, retrospective study of the treatment of Perthes' disease, by simple bed rest, by bed rest in an abduction cast and by varus osteotomy, respectively, is presented A radiological evaluation of the head of the femur at the time of primary healing was used The sphericity of the head, the height and the radius of the epiphysis were measured with the aid of a Moses plastic template

Patients treated within 3 months from the time of their first symptoms had on average less deformity of the head of the femur than had patients treated later It is concluded that none of the methods of treatment studied was superior or inferior, to another

SCINTIGRAPHIC GROUPING OF PERTHES' DISEASE

O J Fasting, I Bjerkreim, N Langeland L

Oslo

A new method for early grouping of Perthes' disease according to femoral capital epiphysis in

months of the onset of symptoms

The grouping according to femoral head involvement was based on the size of the area with decreased activity, visible on the scintigraphic image This method seems to open up new possibilities for comparing the different treatments given in the early stage of the disease The scintigraphic grouping correlated fairly well with the radiological grouping in the fragmentation stage, except in cases treated within 1 month of the onset of symptoms who all "gained" in grouping, indicating that early treatment is of importance

COMPLICATIONS IN THE

IONS

24 CASES

Rolf Hagen
Martina Hansens Hospital, Sandvika

It is generally accepted that steroid medication is responsible for the bone necrosis spontaneous fractures, tendon ruptures and affections of the epiphysial growth plates which follow kidney transplantations.

In co-operation with Surgical Department B Rikshospitalet, where most kidney transplantations in Norway are performed, 24 patients with various complications arising from the

usculo-skeletal system in 500 transplantations are ported.

Two were treated with a total prosthesis, and z with arthrodesis of the hip joint, one had in-trochanteric osteotomy for epiphyseolysis of the ad of the femur, and two had calcaneal tendon pairs. The remaining patients were treated with n- or partial weight-bearing and started on metric exercises.

STRUCTURAL MODEL OF THE UMAN SPINE

mes A. Ashton Miller
phies Minde Orthopaedic Hospital, Oslo

A two-dimensional structural model of the man ligamentous spine with a minimum set of rinsic muscles required for equilibrium was pre nted. Input data for segmental flexibility and unk mass distribution were taken from the blished data of others. The results showed the stribution of muscle and reaction forces, as well deflections, along the length of the spine 1–L5). Maximum values for the muscle and ial compressive forces occurred at the thoraco-mbar junction in the spine with normal AP ometry.

[illegible]

In 1962, 52,500 chest roentgenograms minifilms) were taken in the county of Finnmark uring a survey for tuberculosis. This represented 52 per cent of the population over 6 years of ge. Until now 21,130 minifilms have been amined. Of these 6,200 are children 7–18 years ld, 2,300 collected from traditional Lapp com-unities and 3,900 from towns along the coast here the population is predominantly non-appish.

Evidence of scoliosis (> 10° Cobb) was found in 0 minifilms (1 per cent). Analysing the date ccording to race, it was found that the incidence as 0.5 and 1.3 per cent for Lapps and non-apps, respectively.

OPERATIVE RESULTS AND THE USE OF THE PROSTHESIS AFTER LOWER LEG AMPUTATIONS

Anders Dahle
Regional Hospital, Trondheim

One hundred and forty nine amputations of the lower extremities in 109 patients were evaluated.

Sixty-one per cent of the patients were males, and 80 per cent were older than 60 years. Indications for amputation were peripheral vascular disease in 76 per cent. Most of the operations were done below-knee.

Twenty-five per cent of the patients died in the hospital.

Wound healing healing was better the higher the amputation.

About half of the amputees were considered suitable for fitting of a prosthesis, and 10 per cent of these died in the hospital. Eighty four per cent of the patients used their prosthesis for a shorter or longer time after they left the hospital.

HALO PELVIC TRACTION IN SCOLIOSIS

I. Bjerkreim
Sophies Minde Orthopaedic Hospital, Oslo

Halo-pelvic traction is the most effective method of preoperative traction in the treatment of scoliosis, and the patients can ambulate.

A 6-year-old girl with an infantile idiopathic scoliosis was demonstrated. She was first seen when 9 months old. In spite of conservative treatment the scoliosis progressed, at 4 years it measured 110°, and at 6 years 140°. A halo-pelvic apparatus was applied, and 2 months later the curve had reduced to 57°. A spine fusion from T 4 to L 3 was then done, using a modified Harrington technique with instruments of small dimension, and the halo-pelvic apparatus was replaced by a Milwaukee brace 10 weeks later. The combination of the halo-pelvic traction and the spine fusion with the Harrington technique reduced the scoliosis curve from 140° to 50°. The patient increased 14 cm in height.

NERVUS INTEROSSEOUS ANTERIOR SYNDROME

Knut Skoglund
Regional Hospital, Trondheim

Three patients with isolated paralysis of the anterior interosseous nerve, which is the largest motor branch of the median nerve, are presented.

The clinical picture was a spontaneous paralysis of m flexor pollicis longus and m. flexor digitorum profundus to the index finger in two patients, and an isolated paralysis of the latter in one patient They all demonstrated a typical thumb-index pinch, with the distal joints of the affected fingers held in hyperextension and the joint proximal to these in increased flexion

Surgical exploration of the anterior interosseous nerve did not reveal any constrictive structure in relation to the nerve An external neurolysis was performed in two of the patients, and in all three cases tendon transpositions were done with good functional results

ARTHRODESIS OF THE KNEE USING TWO PLATES

Olav Nesse
Regional Hospital, Trondheim

Technique The denuded joint is, after compression, fixed with two long vitallium plates, one on each side

Material. Twenty-four cases are reported, six males aged 54 to 73 years, and 18 females aged 49 to 81 years. All had severe destruction of the knee joint with pain, and/or instability and deformity

Indications Osteoarthritis or post-traumatic arthritis 11, rheumatoid arthritis 8, poliomyelitis 2, tuberculosis 1, osteomyelitis 1, and re-arthrodesis 1

Results After 4 months there was clinical and roentgenological evidence of fusion, and all patients were pain-free and completely satisfied, except for one who complained of pain related to the plates.

Complications Two patients had thrombosis of lower leg, and one cerebral thrombosis. [illegible] wound infection occurred in two

Advantages of the method Free choice of knee position, no external support required Walking on crutches can be permitted the day after operation, and quick union is achieved.

Oslo, November 19th, 1977

CLINICAL FAT EMBOLISM SYNDROME

Antti Alho
Helsinki University Central Hospital, Helsinki

In a series of 556 patients with multiple injuries, fulminant fat embolism syndrome (FES) was diagnosed in 6 per cent, and a less severe type in 12 per cent of the patients. All FES patients had fractures of the pelvis and long bones, the frequency in the non-FES patients was 54 per cent 55 per cent of the FES patients, and 60 per cent of the non-FES patients were hypoxaemic at admission Various conditions causing post-traumatic pulmonary insufficiency were observed in the latter group

The management of FES consisted of adequate respiratory care, careful immobilization, and early osteosynthesis of the fractures, and in a selected group, a pharmacological dose of Solu Medrol (10 mg/kg i v, t i d) during the first day which reduced the signs significantly The mortality in the whole series was 11 per cent, in the FES patients 6 per cent

It is concluded that FES complicating fractures is a well-defined entity among the various types of post-traumatic pulmonary insufficiency

SCREW FIXATION VERSUS PRIMARY PROSTHETIC REPLACEMENT IN ACUTE DISPLACED FEMORAL NECK FRACTURES

Tor Steiner Raugstad, Odd Søreide & Anders Mølster
Haukeland Hospital, Bergen

One hundred and four patients with femoral neck fractures were randomized according to birth date In one-half of the patients the fractures were fixed with von Bahr screws and the other half had the femoral head replaced by a Christiansen hemiprosthesis. Full weight bearing was allowed in both groups. The mean operation times were 38 and 86 minutes, respectively

During the first year mechanical failure occurred in 11 patients with screw fixation Avascular necrosis of the head of the femur occurred in 2 patients but there were no cases of non union Dislocation of the prosthesis occurred in 6 patients, and one patient developed deep infection.

The results at the 1-year follow up (Stinchfield classification) were In the group with [illegible] good 52 [illegible]

per cent, respectively The results are [illegible] in favour of primary prosthesis.

DIAGNOSIS OF KNEE LIGAMENT INJURIES

Anders Mølster, Stein Haukaas & Antti Alho
Haukeland Hospital Bergen

A series of 51 knee ligament injuries were tested for instability *ad modum* Houghston. Thirt[illegible] patients were operated on.

Examination under anesthesia was performed in patients who received non-operative treatment even a suspicion of instability could be disproven.

In indication for operation was found in the

...

of 24 triad injuries, and three out of five us and posterior hyperextension injuries. In operated patient no ligament injury could be nd.

It is concluded that careful and repeated preoperative clinical instability testing gives a correct gnosis in most knee ligament injuries, and aids planning the operative treatment

TERNAL FIXATION OF LVIC FRACTURES

tti Alho
ukeland Hospital, Bergen

Fixation of hemipelvic fractures with Hoffmann eotaxis pins in the anterior iliac crests is pain-eving, reduces the lateral opening of the pelvic g and has a haemostatic effect In these pects it is superior to the pelvic sling The me constructions do not, however, effectively interact the cranial dislocation which is an portant factor for residual disability

A double frame with four transversal tie bars d a distractor in the cranial side bar on the side of dislocation, gave the best reduction, and stability, in a biomechanical laboratory study

Oslo, December 10th, 1977

PRENATAL DEVELOPMENT OF THE HIP JOINT

Per Helland
Central County Hospital Kristiansand

Two different autopsy studies one from India and one from USA, on prenatal development of the hip joint, are compared and discussed

The degree of anteversion seems to be greater prenatally in normal hips in western countries than in India

ARTHROSCOPY OF THE KNEE JOINT

Odd Haerum
Central County Hospital, Kristiansand

Seventy seven arthroscopies of the knee joint, unsuccessful in eight, are reported.

Subsequent arthrotomy in 62 cases revealed misinterpretation of the arthrosopic findings in nine instances (17 per cent) In the 36 most recently performed arthroscopies the misinterpretation was reduced to 5 5 per cent. It is concluded that arthroscopy requires skill and experience to obtain maximum benefit

IN MEMORIAM



Dr Henrich Steffens Nissen-Lie died on May 22nd, after a relatively short illness, at the age of 75 years. After a full and satisfying life, a fine person and a man of outstanding capabilities has passed away

It is not easy to give an adequate description of Henrich Nissen-Lie in a few words. Superlatives are called for, while at the same time we know that he himself was utterly modest in all ways, including his use of words This modesty, so characteristic of Nissen-Lie, was in harmony with the other foremost qualities in his personality, unselfishness, absolute integrity and unshakeable resolution. Nissen-Lie endeared himself to all who were privileged to know him and his modesty, steadfastness and compassion made him beloved as a physician Even in untreatable cases he used his medical prowess to the utmost for the relief and consolation of his patients and won their devotion

Nissen-Lie graduated in medicine in 192 He gained a broad experience in orthopaedi and over the years published a seri of valuable clinical works Because of h wide ranging interests in both classic orthopaedics and traumatology he became bridge-builder between the two fields to th great benefit of Norwegian orthopaedics. H was one of the founding members of th Norwegian Orthopaedic Association and i President from 1953–1955 After service the Department of Surgery at Ullev Hospital in the years from 1949–1956 wh he was also a lecturer at the University Oslo, he became chief of staff Kronprinsesse Marthas Institutt in 195 Under his leadership, this hospital became centre for rheumatic and hand surgery an the neurological aspects of orthopaed surgery in Norway He was one of th founding members of the Scandinavia Society for Hand Surgery established in 195 Nissen-Lie was a member of the committ of the Scandinavian Orthopaedic Associatio and President from 1966–1968 He was a c editor of Acta Orthopaedica Scandinavi from 1966–1972

For services to Norwegian orthopaed surgery he was made an honorary member the Norwegian Orthopaedic Association 1972, and at an international level he w elected an honorary member of the Briti Orthopaedic Association in 1968 In 1973 h was knighted (Knight of the Order of S Olav) for his efforts on behalf of orthopaed surgery In the same year he retired fro Kronprinsesse Marthas Institutt upo reaching retirement age

Nissen Lie was for many years a enthusiastic cruising and racing yachtsma and his trophies include a Royal Cup A fi sportsman, who will also be sadly missed b yachting colleagues

May he rest in peace

Arne Rugtv

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The manuscript including tables and figures should, if possible, be sent in duplicate to facilitate rapid refereeing and the author should retain a further copy for his use. No roman numerals should be used in the text decimal fractions a full stop, and not a comma, used. The "% sign should be replaced in the text by cent" The minus sign should be shown as –

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